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Bistatic Radar Cross Section of a Perfectly Conducting Rhombus-Shaped Flat Plate

A. J. Poggio

Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LEXINGTON, MASSACHUSETTS

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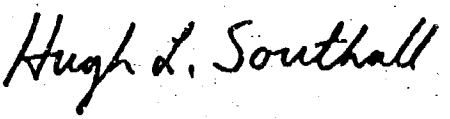
This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER



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BISTATIC RADAR CROSS SECTION OF A PERFECTLY CONDUCTING RHOMBUS-SHAPED FLAT PLATE

A.J. FENN
Group 61

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ABSTRACT

The bistatic radar cross section of a perfectly conducting flat plate that has a rhombus shape (equilateral parallelogram) is investigated. The Ohio State University electromagnetic surface patch code (ESP version 4) is used to compute the theoretical bistatic radar cross section of a 35- × 27-in rhombus plate at 1.3 GHz over the bistatic angles 15° to 142°. The ESP-4 computer code is a method of moments FORTRAN-77 program which can analyze general configurations of plates and wires. This code has been installed and modified at Lincoln Laboratory on a SUN 3 computer network. Details of the code modifications are described. Comparisons of the method of moments simulations and measurements of the rhombus plate are made. It is shown that the ESP-4 computer code provides a high degree of accuracy in the calculation of copolarized and cross-polarized bistatic radar cross section patterns.

Electromagnetic surfaces; Method of moments; Computer programs; Radar cross sections

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

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1. INTRODUCTION

In radar cross section (RCS) measurements of complex targets it is desirable to make additional measurements of reference targets such as flat plates and cylinders for which the radar cross section is readily computed. These reference targets are used in checking the calibration, target quiet-zone characteristics, and mechanical alignment of the measurements system. This report addresses the simulated RCS of a perfectly conducting flat plate used in bistatic measurements. Depicted in Figure 1-1 is a typical geometry for bistatic RCS measurements. The angle β denotes the bistatic angle which is fixed, and the angle θ denotes the target rotation angle or aspect angle.

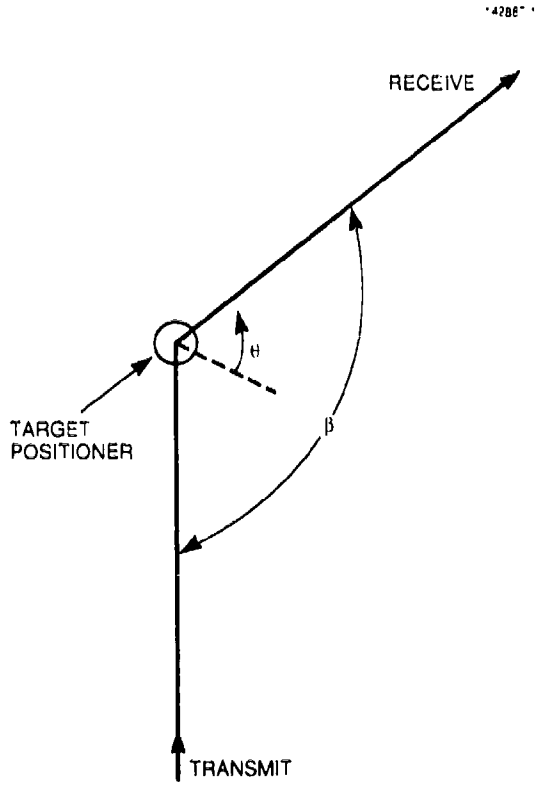


Figure 1-1. Geometry for bistatic radar cross section measurements. The angle β is the bistatic angle, and the angle θ is the target rotation angle.

Except for spheres and cylinders, little published data exist for the far-field bistatic radar cross section of targets [1-3]. The bistatic scattering from a sphere is readily computed [4] and is often used as a primary calibration standard in RCS measurements. Bistatic scattering analyses and measurements for a conducting cylinder of finite length are described in [5-8]. Monostatic scattering from square and circular flate plates is treated thoroughly in [1-3]. A physical optics formulation for the bistatic scattering of a polygonal flat plate is reviewed in [3]. The bistatic RCS

of rectangular and triangular plates has been calculated in [8]. The purpose of this report is to compare simulated and measured data for a rhombus-shaped (equilateral parallelogram) flat plate over a broad range of bistatic angles.

A method of moments code called ESP-4 (electromagnetic surface patch code: version 4) which is capable of analyzing a wide variety of antenna or radar cross section problems has been developed at The Ohio State University [9]. The software can analyze complex geometries involving multiple-connected plates and/or wires and is well-suited to analyzing the scattering from an isolated quadrilateral plate like the rhombus. Many of the subroutines in the ESP-4 code are based on subroutines from an earlier wire-grid RCS/antenna method of moments code developed by Richmond [10]. Wire-grid modeling of a continuous surface, such as a flat plate, is approximated with closely spaced conducting wires [11]. A similar wire-grid moment method computer code is described in [12]. In contrast, surface patch modeling allows a piecewise-continuous approximation to a complicated surface. Surface patch modeling requires fewer unknowns than wire-grid modeling; hence, larger surfaces can be modeled. ESP-4 utilizes the electric field integral equation (EFIE) to enforce the boundary condition of the tangential electric field being zero at the surface of the antenna/target of interest. The EFIE solution allows for either open or closed surfaces. The basis and testing functions used in this code are piecewise sinusoidal. The surface patches (or surface current modes) are assumed to have zero thickness and are quadrilateral dipoles which are useful in modeling an arbitrary-shaped body. For a complete description of the theory and capabilities of the ESP-4 code, the reader is referred to the user's manual [9]. Other moment method codes exist which are based on the magnetic field integral equation (MFIE) for closed surfaces [13,14] and EFIE for arbitrary surfaces [15-17]. The EFIE moment method formulation used in [15-17] differs from the ESP-4 formulation in that triangular-shaped basis functions with pulse weighting are used for the surface current mode vectors.

This report is organized in the following manner: In Section 2, details of the modifications made to the electromagnetic surface patch code ESP-4 are given. The basic modifications of the ESP-4 code are a change in the input data structure and a new option for fixed bistatic angle RCS patterns. A listing of the revised ESP-4 main program is given in the appendix. Bistatic RCS patterns for a 35- × 27-in rhombus flat plate at 1.3 GHz are computed with the ESP-4 code and the results are given in Section 3. Bistatic angles from 15° to 142° have been considered as well as two plate orientations (untilted and tilted). The method of moments simulations are compared against measured data and good agreement is demonstrated.

2. ELECTROMAGNETIC SURFACE PATCH CODE (ESP-4) MODIFICATIONS

The purpose of this section is to describe the modifications made to the main program of The Ohio State University (OSU) electromagnetic surface patch code (ESP-4). This software was obtained in July 1988 from OSU and has since been modified at Lincoln Laboratory. The important modifications are the addition of namelist input data and an option for bistatic radar cross section calculation with a fixed bistatic angle and variable target rotation. A complete description of how to use the ESP-4 code can be found in the user's manual [9]. The revisions to the ESP-4 code are summarized graphically in Figure 2-1 and are described in detail in Sections 2.1 and 2.2.

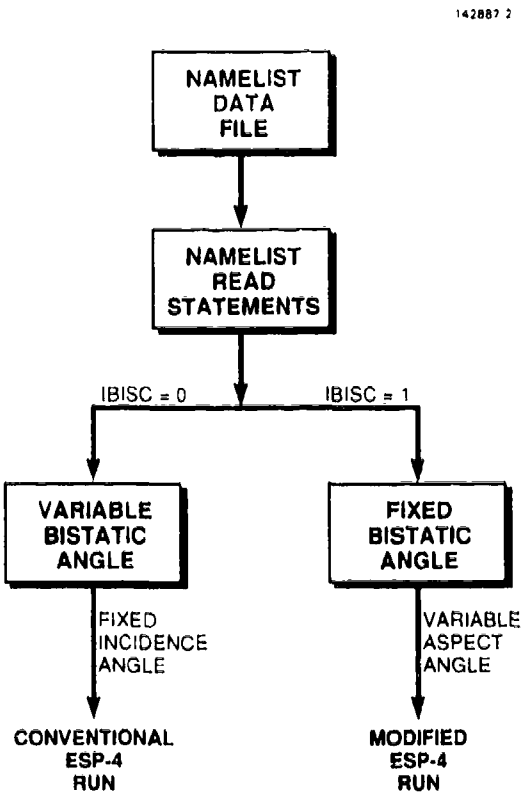


Figure 2-1. Block diagram depicting the revisions made to the ESP-4 computer program. The input data have been restructured, and a new option for fixed bistatic angle RCS pattern computation has been added.

2.1 MODIFICATIONS TO INPUT DATA

The original ESP-4 code defined plate/wire geometries and antenna/RCS pattern cuts through a series of free-format [READ(11,*)] read statements on device 11. There are nearly 80 input parameters in the input data file and the addition of FORTRAN NAMELISTS, where every input quantity is clearly defined, is very attractive. When a NAMELIST is used, the input data are in free format and a typical input parameter, say A, is of the explicit form A=1.0, for example. The NAMELIST data file is helpful in constructing input files for the ESP-4 program that are user-friendly and easily debugged. The present Lincoln Laboratory version of ESP-4 has attempted to keep the definition of the input parameters the same as in the OSU ESP-4 user's manual [9]. The manual should be consulted for the definition of most of the input parameters. Here, only newly defined parameters (input variables) will be defined. Nine namelists have been added to the ESP-4 code and all READ(11,*) statements have been commented. The NAMELIST reads have the form READ(11,NAM) where NAM is the name of the NAMELIST. The added namelist statements (in FORTRAN) are summarized below and follow line ESP01650 of the ESP-4 code.

```
 NAMELIST /RNCTRL/NGO,NPRINT,NRUNS,NWGS,IWR,IWRZT,INT,INTP,INTD,
2INWR,IRGM,IFIL,RF,INDZI
 NAMELIST /FSWEEP/FMC1,FMC2,DFZI,DFF,IRS12,THRD,PHRD,THRI,PHRI
 NAMELIST /PATTRN/IFE,IPFE,FNDFE,PHFE,IFA,IPFA,FNDFA,THFA,
2ISE,IPSE,FNDSE,PHSE,THIN,PHIN,ISA,IPSA,FNDSA,THSA,
3AZRANG,ELRANG,AZMIN,ELMIN,IBISC,BETA,NPTBIS,BANGRG
 NAMELIST /FWIRET/FMC,CMM,A,NPLTS
 NAMELIST /PLATEG/NCNRS,SEGM,IREC,IPN,IGS,ZSHT,XP,YP,ZP
 NAMELIST /SAVEZ/IWRZM,IRDZM
 NAMELIST /WIREAG/NM,NP,NAT,NFPT,NFS1,NFS2,X,Y,Z,IA,IB
 NAMELIST /GENLOD/IFMM,IABB,VLGG,ZLL
 NAMELIST /ATTACH/NASAT,IABAT,NFLA,VGA,ZLDA,BDSK
```

The relation between the new namelists and the old read statements is as follows:

- RNCTRL=READ #1
- FSWEEP=READ #1A
- PATTRN=READS # 2,3,4,5 with the addition of parameters AZRANG, ELRANG, AZMIN, ELMIN, IBISC, BETA, NPTBIS, BANGRG described in Section 2.2.
- FWIRET=READ #6 with the addition of the parameter NPLTS (number of plates) from READ #7. Namelist PLATEG (described next) is read NPLTS number of times.
- PLATEG=READS # 7, 8, 9 with the substitution of explicit (XP, YP, ZP) coordinates in array format for the corners of plate NPL. The software then fills in the original three-dimensional PCN arrays (see ESP-4 manual) which contain the plate corner coordinates.

- SAVEZ=READ #10
- WIREAG=READS #11, 12, 13
- GENLOD=READ #14 is executed NFPT times corresponding to the number of feed points.
- ATTACH=READ #15 is executed NAT times corresponding to the number of attachment points between plates and wires.

2.2 MODIFICATIONS FOR FIXED BISTATIC ANGLE RCS PATTERNS

Consider Figure 2-2 which shows the bistatic geometry for an arbitrary target. The pair of angles (θ_i, ϕ_i) denotes the incident direction and, similarly, (θ_s, ϕ_s) denote the scattering direction. The original version of ESP-4 assumed in a bistatic calculation that the angle of incidence was fixed

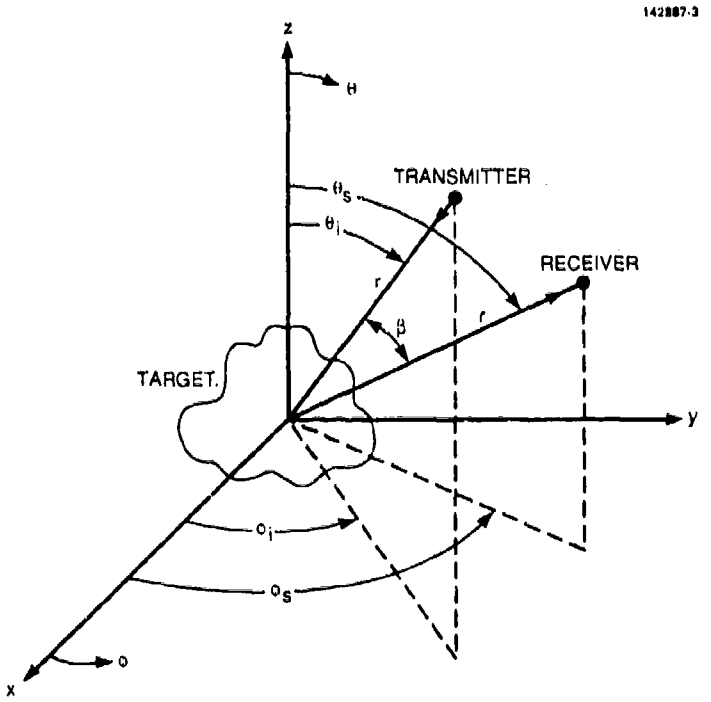


Figure 2-2. Geometry for bistatic radar cross section computation in the ESP-4 computer program.

and the scattering direction (or observation angle) was variable. Thus, the software computes the bistatic RCS pattern as a function of bistatic angle. As described earlier in Figure 1-1, this differs

from a typical bistatic RCS measurement where the bistatic angle is fixed and the target rotation angle varies. The Lincoln Laboratory version of ESP-4 uses a new option, IBISC=1, which fixes the bistatic angle BETA and increments the incident and observation angles appropriately. The implementation of the new option occurs, primarily, following line ESP14200. Note: If IBISC=0 or is not specified, then the code performs in the original bistatic mode where the angle of incidence is fixed and the observation angle varies. When IBISC=1, NPTBIS is the number of target rotation angles and BANGRG is the angular range of target rotation in degrees. BANGRG can be a positive or negative number, as appropriate, to determine the target rotation direction (clockwise or counterclockwise). The original scattering indicators ISE, ISA must be set equal to the appropriate value to invoke bistatic RCS computation in the appropriate elevation or azimuth plane. For example, for scattering in the elevation plane (ϕ is constant) the following three lines of input data are appropriate:

```
ISE=2,IPSE=1,FNDSE=3.0,PHSE=0.0,THIN=90.0,PHIN=0.0,ELRANG=360.,
ISA=0,IPSA=1,FNDSA=3.0,THSA=90.0,
IBISC=1,BETA=120.,NPTBIS=121,BANGRG=-360.,
```

ISE is set equal to 2 to indicate that bistatic scattering in the elevation plane is desired. ISA is set equal to 0 to indicate that an azimuth plane scattering pattern is not desired. IBISC is set equal to 1 to invoke the fixed bistatic angle option with BETA=120, the bistatic angle in degrees; NPTBIS=121, the number of target rotation angles for the fixed bistatic angle; and BANGRG=−360, the angular range of target rotation in the counterclockwise direction (+360 would produce clockwise rotation). With IBISC=1, PHIN=0.0 in the first data line is used; however, the value of THIN is computed within the new section of code. The initial value of THIN is equal to −BETA/2 and is then uniformly incremented within a new DO LOOP (DO 1920 IBIS=1,NPTBIS) over the target rotation angular range BANGRG. The initial observation angle or scattered angle is initially set equal to +BETA/2 and is similarly incremented. If the target is a flat plate located in the xy plane, then the first point computed by the ESP-4 code is the bistatic specular response. This fact is due to the broadside direction being chosen as the bisector of the bistatic angle. This choice is arbitrary and can be changed as desired within the revised ESP-4 code between lines ESP14200 and ESP14240. Note: In the above three data lines if IBISC is set to 0, then the program would compute a bistatic pattern in the elevation plane based on the values given in the first data line above. Thus, the program would run as in the original version of ESP-4.

The original ESP-4 code assumes that azimuth and elevation antenna/RCS patterns cover a full 360° angular range. New parameters, AZRANG, ELRANG have been included in the input data to cover an arbitrary azimuth and elevation range, respectively. Additionally, to start patterns at an arbitrary azimuth or elevation angle, AZMIN and ELMIN, respectively, have been defined. The default values of AZMIN and ELMIN are zero so that they do not have to be defined in the input data file. Further, the line involving IBISC does not have to be defined in the input data since appropriate default values are specified prior to the READ(11,PATTRN) statement. It should be noted that when the new bistatic option is used, the parameters AZRANG and ELRANG are automatically set equal to zero. This effectively forces the number of scattering angles equal to one for a given incident angle. Other minor changes to the code are documented with comments in the modified ESP-4 code listed in the appendix.

3. RESULTS

3.1 RHOMBUS PLATE MODEL

For a general rhombus flat plate, as shown in Figure 3-1, let L and W represent the diagonal

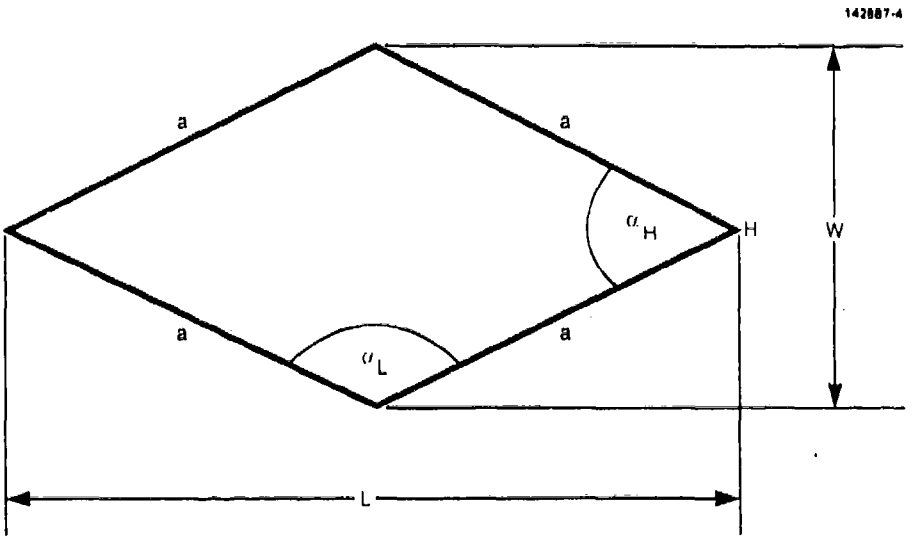


Figure 3-1. Geometry for a rhombus flat plate. The rhombus characteristics (side length, interior angles, and area) are readily computed from the diagonal length L and diagonal width W.

length and diagonal width, respectively, and let a be the side length. The side length of the rhombus is computed according to

$$a = \frac{\sqrt{L^2 + W^2}}{2} \tag{3.1}$$

and the area A, is given by

$$A = \frac{1}{2} LW. \tag{3.2}$$

The rhombus interior angles α_L and α_W are computed using

$$\alpha_L = 2\sin^{-1}(\frac{L}{2a}) \tag{3.3}$$

$$\alpha_W = 2\sin^{-1}(\frac{H}{2a}). \tag{3.4}$$

The specular monostatic radar cross section of the flat plate is given by the well-known equation

$$\sigma = \frac{4\pi A^2}{\lambda^2}. \tag{3.5}$$

A sketch of the rhombus flat plate target under consideration is shown in Figure 3-2. The plate has a diagonal length $L = 35$ in and a diagonal width $W = 27$ in. The length of each of the

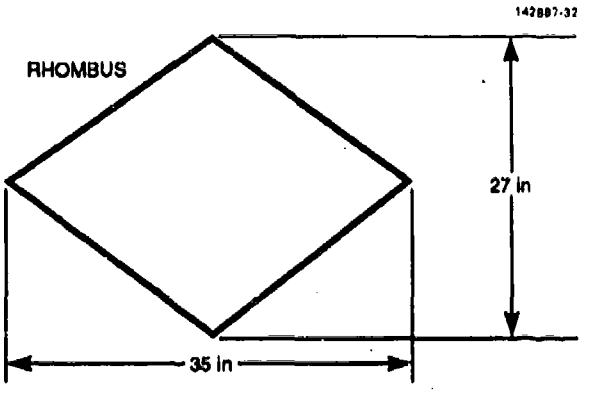
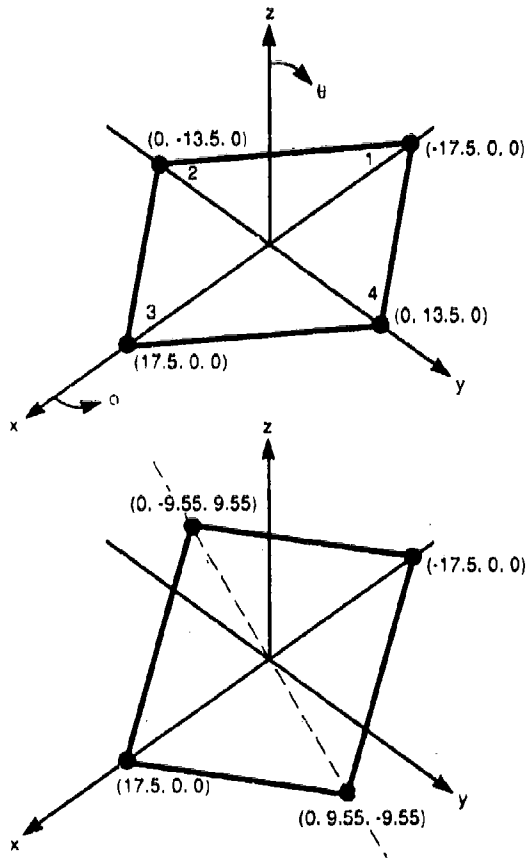


Figure 3-2. Rhombus plate with diagonal length $L = 35$ in and diagonal width $W = 27$ in used both in ESP-4 simulations and in measurements.

four sides is approximately 22.1 in. The acute angles of this plate are $\alpha_W = 75.3°$ and the obtuse angles are $\alpha_L = 104.7°$. In terms of wavelength, at the frequency of interest 1.3 GHz, the electrical dimensions of the plate are $L = 3.85\lambda$ and $W = 2.97\lambda$ and the plate area is 5.74 square wavelengths. The thickness of the experimental plate is 0.5 in or 0.055λ and the plate is simulated using zero thickness. For the given plate dimensions, the specular monostatic radar cross section is computed (using Equations 3.2 and 3.5) to be 13.4 dBsm at the desired frequency 1.3 GHz. Figure 3-3 shows a three-dimensional view of the plate located in the rectangular coordinate system for two plate orientations. In Figure 3-3(a), the plate is in the xy plane and in Figure 3-3(b), the plate has been rotated by 45° with respect to the y axis. In this report, the RCS pattern cuts are always taken in the xz plane. Notice that the long dimension of the plate (35 in) is oriented in the x direction. A two-dimensional view (looking along the x-axis) of the plate in untilted and tilted configurations is shown in Figure 3-4. The bistatic geometry for the plate is depicted in Figure 3-5. Note that the



NOTE: ALL DIMENSIONS ARE IN INCHES

Figure 3-3. Three-dimensional view of rhombus plate in (a) untilted and (b) tilted orientation (rotated 45° about the x axis). All RCS patterns in this report are taken in the xz plane.

angle θ represents the effective target rotation angle for the fixed bistatic angle β. When $\theta = 0°$, the perpendicular direction to the plate is at the bisector of the bistatic angle.

The ESP-4 code was used to analyze the bistatic scattering patterns of the rhombus plate. Bistatic angles of 15, 45, 90, 120, and 142° were considered corresponding to available 35- × 27-in rhombus flat plate measured RCS data collected in 1987 at the US Air Force Radar Target Scatter Facility (RATSCAT)[18]. The important input data for the ESP-4 RCS simulations are listed below with a description of the parameters.

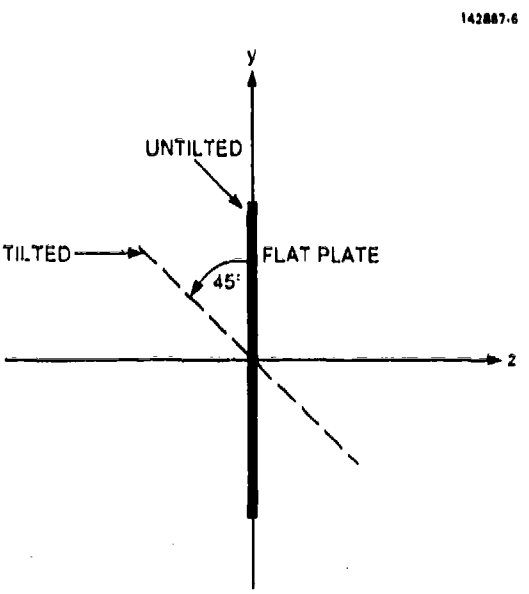


Figure 3-4. Two-dimensional view (looking along the x-axis) of the plate in untilted and tilted configurations.

```
&RNCTRL  (Run control parameters)
  NGO=1,NPRINT=2,NRUNS=1,NWGS=1,IWR=0,IWRZT=0,INT=4,INTP=6,INTD=18,
  INWR=0,IRGM=1,IFIL=0,RF=-1.0,INDZI=0,
 &
```

In NAMELIST RNCTRL, the parameter NGO=1 runs the ESP-4 program from start to finish. Printout of input parameters and target geometry is implemented with NPRINT=2. The program is executed one time (NRUNS=1) and NWGS is not used. The parameters IWR and IWRZT are both set to zero which means that the induced modal currents and impedance matrix elements, respectively, are not printed out. The parameter INT is not used. The number of Simpson's rule integration intervals used in integrating over the surface patch monopoles is specified by INTP=6. The parameter INTD is not used and INWR=0 means that there are no wires in the target geometry. The parameter IRGM is not used. The parameter IFIL=0 means that full surface patch test modes are used, and RF=−1 performs a far-field computation. The parameter INDZI is set to zero which means do not perform a frequency sweep computation.

```
 &PATTRN  (Pattern specifications)
  IFE=0,IPFE=1,FNDFE=3.0,PHFE=90.0,
  IFA=0,IPFA=1,FNDFA=3.0,THFA=90.0,
  ISE=2,IPSE=1,FNDSE=3.0,PHSE=0.0,THIN=90.0,PHIN=0.0,ELRANG=0.,
```

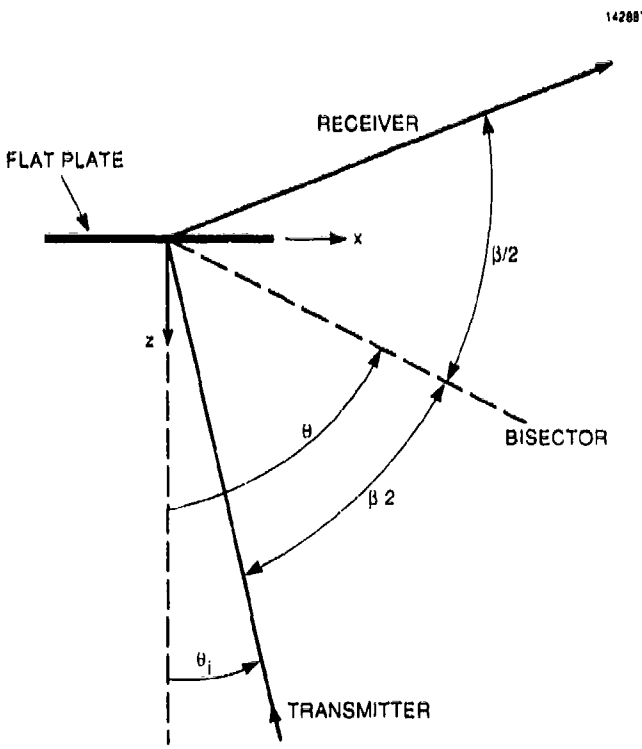


Figure 3-5. Bistatic geometry for flat plate. The bistatic angle is fixed and the target aspect angle θ varies. Note that $\theta = 0°$ corresponds to the specular bistatic RCS.

```
 ISA=0,IPSA=1,FNDSA=3.0,THSA=90.0,
 IBISC=1,BETA=120.,NPTBIS=121,BANGRG=-360.,
&
```

The third and fifth lines of the PATTRN NAMELIST indicate that a bistatic scattering elevation pattern (ISE=2) with the new fixed bistatic angle option (IBISC=1) is used. The bistatic angle is defined by BETA=120 (degrees). The azimuth cut angle (ϕ) is PHSE=0 (degrees), which produces a pattern in the xz plane. The incident wavefront azimuth angle (ϕ_i) is PHIN=0 (degrees). The number of target rotation angles is NPTBIS=121, and the range of target rotation is BANGRG=−360 (counter clockwise rotation). Lines 1, 2, and 4 of PATTRN indicate that no other pattern cuts are desired.

```
&FWIRET  (Frequency, wire type, and number of plates)
 FMC=1300.0,CMM=38.0,A=0.001,NPLTS=1,
&
```

The frequency has been set to 1.3 GHz (FMC=1300, frequency in MHz) and CMM and A are not used. The number of plates is NPLTS=1.

```
&PLATEG  (Plate geometry)
 NCNRS(1)=4,SEGM(1)=0.2,IREC(1)=0,IPN(1)=3,IGS(1)=0,ZSHT(1)=(0.0,0.0),
 XP(1)=-.4445,0.,.4445,0.,
 YP(1)=0.,-.3429,0.,.3429,
 ZP(1)=0.0,0.0,0.0,0.0,
 &
```

There are 4 corners on the plate [NCNRS(1)=4], and the maximum surface patch segment size is 0.2λ. The parameter IREC(1)=0 means that the plate is polygonal rather than rectangular. The parameter IPN(1)=3 means that two polarizations are used in the surface patch currents. The parameter IGS=0 means that ESP-4 selects a reference side of the plate. A perfectly conducting plate is defined by the complex sheet impedance ZSHT(1)=(0.0,0.0). The four corners of the plate are described in rectangular coordinates by the data arrays XP, YP, and ZP in meters and correspond to the coordinates shown in Figure 3-3(a).

```
&SAVEZ  (Save or reuse impedance matrix)
 IWRZM=1,IRDZM=0,
 &
```

The program saves the impedance matrix for additional runs using the parameter IWRZM=1.

After performing an initial run and storing the impedance matrix, a second run is made in which the impedance matrix is read-in using the following input data:

```
&SAVEZ
  IWRZM=0,IRDZM=3,
 &
```

For the case of the 45° tilted rhombus plate [Figure 3-3(b)] the input plate geometry NAMELIST is given by

```
&PLATEG
  NCNRS(1)=4,SEGM(1)=0.2,IREC(1)=0,IPN(1)=3,IGS(1)=0,ZSHT(1)=(0.0,0.0),
  XP(1)=-.4445,0.,.4445,0.,
  YP(1)=0.,-.2425,0.,.2425,
  ZP(1)=0.0,.2425,0.0,-.2425,
 &
```

The first step in running the ESP-4 code is to verify the target (flat plate) input geometry. This is done by specifying NGO=0 in the input data file. After running the ESP-4 program, an output file is generated which contains the input geometry information. Geometry plotting software called ESP4GM was included with the ESP-4 software and was used to generate visual information about the plate simulation. ESP4GM is a FORTRAN 77 program which utilizes GKS (Graphic Kernel System) software. The results are summarized in Figures 3-6 to 3-9. Figure 3-6 shows the layout of the overlapping piecewise-sinusoidal surface patch modes for both polarizations. For

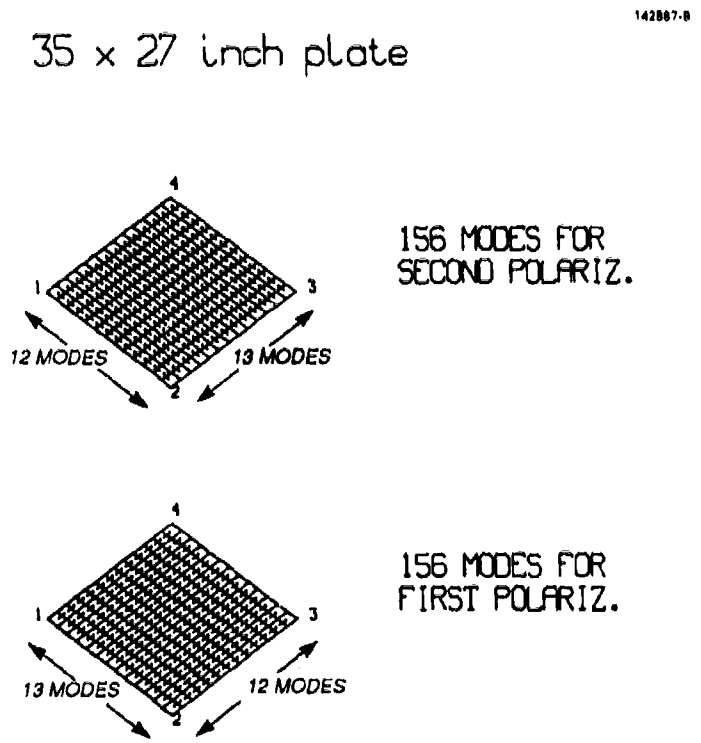


Figure 3-6. Dual-polarized surface patch layout generated by ESP-4 for the 35- × 27-in rhombus plate at 1.3 GHz.

each polarization there are 156 modes arranged in a 12 × 13 grid. In terms of the plate surface area ($5.74\lambda^2$) there are approximately 27 modes (of one polarization) per square wavelength. Each dipole surface patch mode is a parallelogram, and two of these modes arranged side by side form a rhombus, which is similar to the rhombus plate. A detailed (enlarged) view of two contiguous patches of each polarization is depicted in Figure 3-7. The polarization vectors of the two different modes (which are not quite orthogonal) make an obtuse angle with respect to each other that is 104.7° as determined from Equation (3.4). One of the dipole surface patches is made up of two monopole surface patches, each of which has a rhombus shape. In this figure, the side of one of the rhombus-shaped monopole surface patches has a length of 0.187λ. This is found by dividing the side of the rhombus plate, which is 2.43λ, into 13 equal segments. Note that the computer program

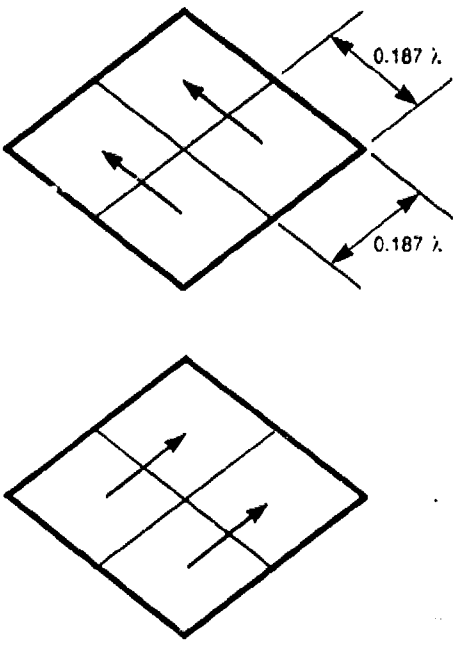
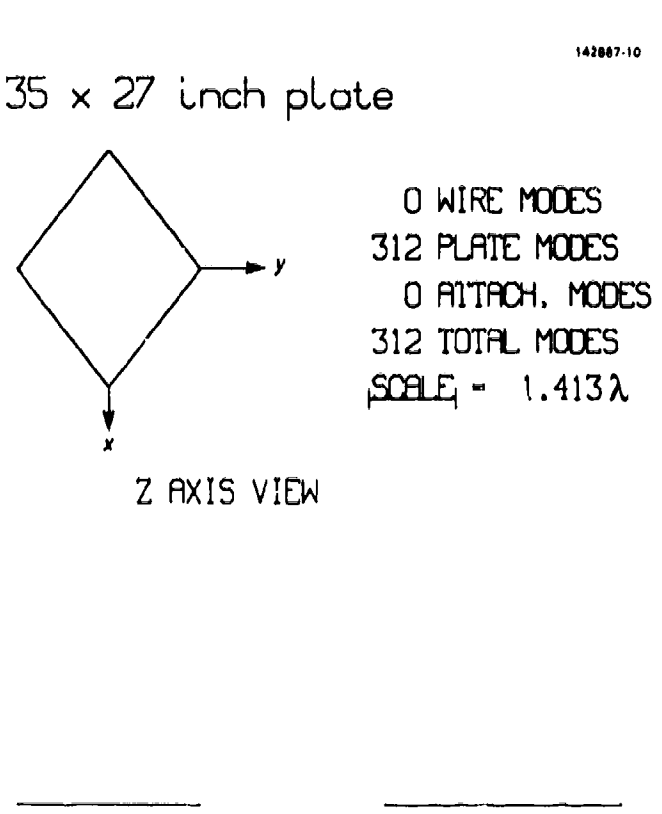


Figure 3-7. Enlarged view of contiguous rhombus-shaped surface patch monopoles from Figure 3-6.

has chosen the size of the patches subject to the maximum patch size specified by the parameter SEGM(1)=0.2 (wavelengths). A three-view plot of the rhombus plate geometry is shown in Figure 3-8 for the untilted plate and in Figure 3-9 for the 45° tilted plate.

3.2 COMPARISON OF SIMULATED AND MEASURED BISTATIC RCS

Using the surface patch basis function layout given in Figure 3-6, the bistatic radar cross section of the rhombus plate at 1.3 GHz was computed by setting NGO=1. An initial run was made where the method of moments mutual impedance matrix is computed and stored in a disk file for later runs. A collection of simulated (with ESP-4) and measured RCS patterns of the rhombus flat plate covering bistatic angles 15° to 142° are shown in Figures 3-10 to 3-27. For all bistatic angles both plate tilt angles (0° and 45°) were used except for the $\beta = 15°$ case where measurements were available only for the untilted case. For the measured data, the notations H and V refer to horizontal and vertical polarization, respectively. A pair of letters, for example HV, refers to horizontal transmit polarization and vertical receive polarization. In the ESP-4 code,

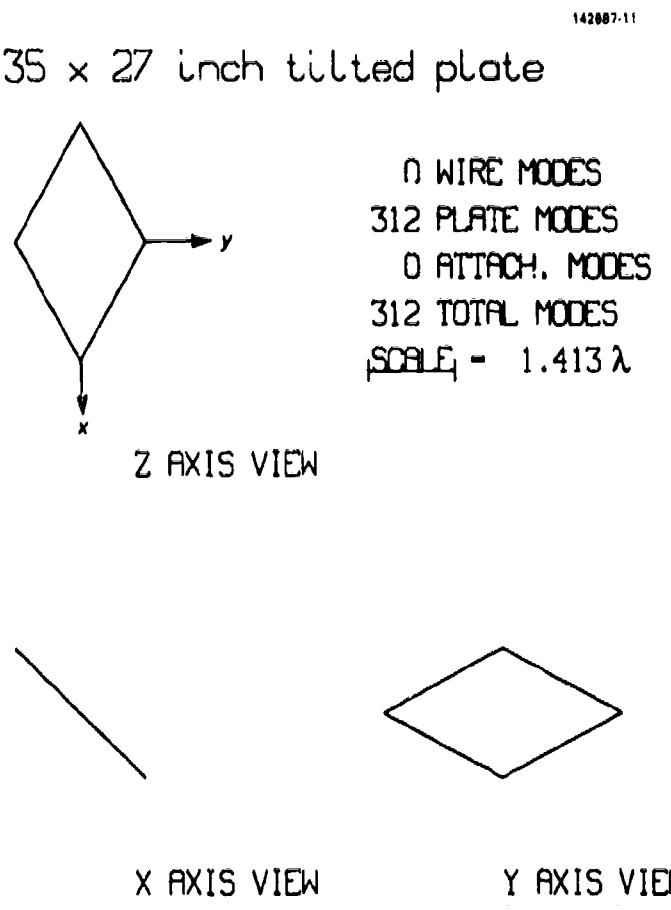


NOTE: COMPUTER OUTPUT; ITALICS ADDED BY AUTHOR

Figure 3-8. Three-view plot of the rhombus plate in the untilted orientation.

spherical components are computed; the θ component is equivalent to H and the ϕ component is equivalent to V. Thus, the relation between the four possible components in the measured and ESP-4 coordinate systems is (HH, VV, HV, VH)$\leftrightarrow$ $(\theta\theta, \phi\phi, \theta\phi, \phi\theta)$. For the remainder of the report, the RCS components will be described using the H and V notations.

Consider first Figures 3-10 and 3-11 which show the RCS patterns for the four polarizations (HH, VV, HV, VH) at the bistatic angle 15°. Notice in Figure 3-10 that the simulated copolarized (HH, VV) components are in good agreement with the measurements. The simulated specular bistatic RCS (13.1 dBsm) agrees closely with the theoretical specular monostatic RCS (13.5 dBsm) computed earlier. In Figure 3-11, the simulated cross-polarized RCS (HV, VH) is below the −45-dBsm level and so the measured data are corrupted by the polarization isolation and background clutter in the measurements. For all the bistatic angles, when the plate is not tilted the simulated



NOTE: COMPUTER OUTPUT; ITALICS ADDED BY AUTHOR

Figure 3-9. Three-view plot of the rhombus plate in the 45° tilted orientation.

cross-polarized RCS is very low, and so the measurements are dominated by isolation/clutter-induced errors. These cross-polarized data appear in Figures 3-14, 3-18, 3-22, and 3-26 and will not be discussed further.

A series of patterns for bistatic angles 45° to 142° are shown in Figures 3-12 to 3-27, where both plate tilt angles are considered. For example, Figure 3-12 is for the HH and VV RCS components at the 45° bistatic angle with no target tilt, while Figure 3-13 is for a plate tilt angle of 45°. Notice that the effect of the plate tilt is to break up the main lobe in both HH and VV components. Good agreement between the measurements and simulations is evident for the copolarized components for this case. Next, in Figures 3-14 and 3-15 the cross-polarized RCS is shown for the untilted and tilted plate, respectively. The effect of tilting the plate is to raise the theoretical cross-polarized response; thus, the measured data bear a resemblance to the simulations as in Figure 3-15. The basic lobing structure is the same for the measurements and the simulations, but the amplitude of individual lobes differs by as much as 10 dB. Next, for the 90° bistatic angle case shown in Figure 3-16 there is a clear broadening of the main beamwidth in HH and VV polarizations, and

the simulations and measurements are in good agreement. Good agreement is also achieved in Figures 3-17 and 3-19 for the tilted plate. Figures 3-20 to 3-23 show the $\beta = 120°$ case results. The main lobe continues to broaden for HH and VV components as shown in Figure 3-20. There is a somewhat better agreement between simulations and measurements for HH compared to VV in Figures 3-20 and 3-21. This discrepancy is likely due to a higher background for VV compared to HH. Finally, Figures 3-24 to 3-27 show the results at the 142° bistatic angle. In Figure 3-24, the specular RCS HH component drops by approximately 6 dB compared to the 120° bistatic case, while the VV component is relatively unchanged. There is a difference of several decibels in the simulated and measured specular responses in both HH and VV components. It is further noted in Figure 3-24 that the HH main lobe has broken up into three, while the VV main lobe continues to broaden compared to the $\beta = 120°$ case. There are significant differences between the simulated and measured lobe amplitudes in both Figures 3-24 and 3-25, but the general shapes are in good agreement. The differences are attributed to an increase in the background level. In Figure 3-27 the agreement between the cross-polarized measured data and simulated data is good. A mirror symmetry between HV and VH components is evident here as should be the case for a symmetric target [19].

The specular response of the copolarized RCS for the untilted plate is summarized in Figure 3-28. The simulated data indicate that the specular response decreases monotonically with increasing bistatic angle and the decrease is more rapid for HH compared to VV. The measured data track the simulated curves very well with the exception of the VV component for $\beta = 142°$ where the measured RCS differs from the simulation by about 2 dB. To check the accuracy or convergence of the ESP-4 simulated RCS patterns at the $\beta = 142°$ case, the rhombus plate was modeled using a finer grid of patches with a maximum segment length equal to 0.15λ. With this maximum patch size, the ESP-4 software generated a 17×16 grid of 272 patches for each polarization with an actual patch segment length equal to 0.143λ. The total number of modes is 544, which is 1.74 times the number of modes used with the 0.2λ maximum patch size simulations. A comparison of the copolarized RCS for HH and VV components with 0.187λ and 0.143λ patches (rounded to 0.19λ and 0.14λ, respectively) for the $\beta = 142°$ untilted plate is made in Figure 3-29. The simulated specular values agree to within 0.1 dB, and the overall good agreement between the patterns indicates an insensitivity to the patch size. Thus, the differences between the measured and simulated specular responses (as well as the responses at other angles) observed in Figure 3-28 are attributed to measurement error.

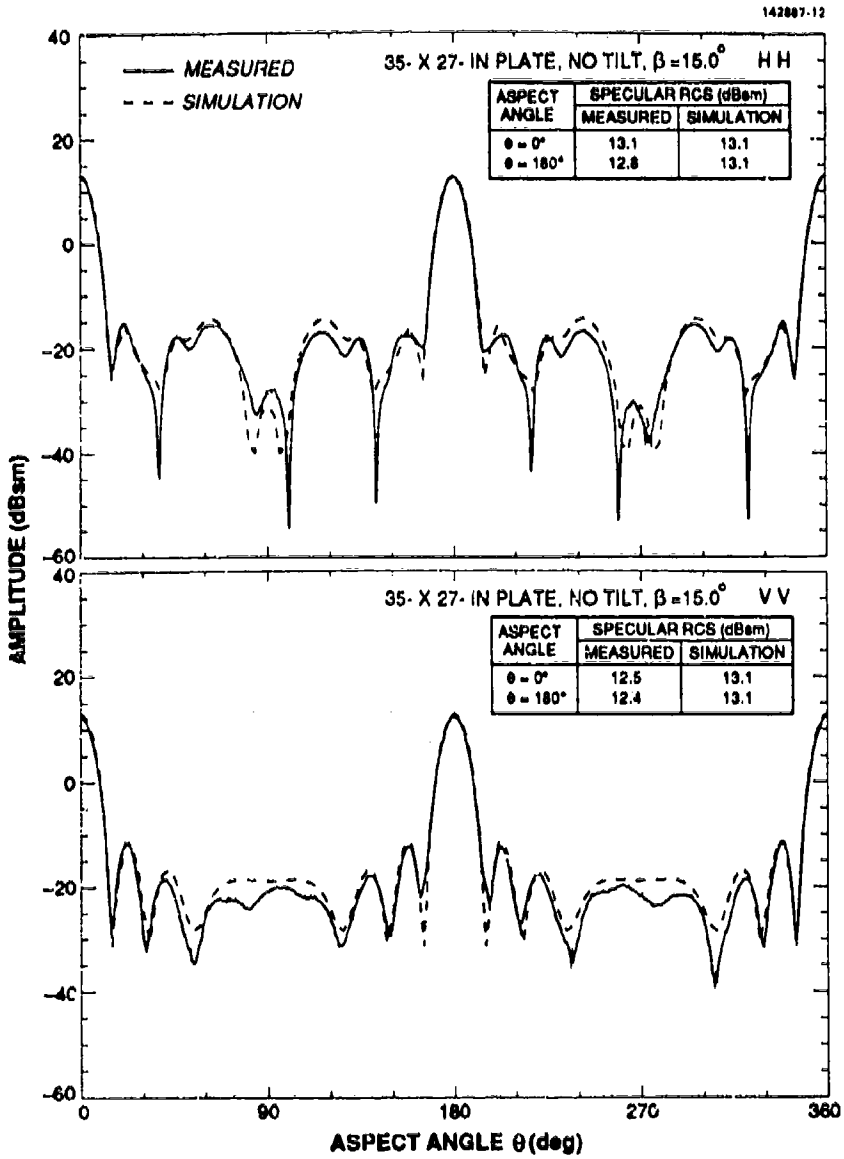


Figure 3-10. Comparison of ESP-4 simulations and measurements of the copolarized (HH, VV) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 15°$ and there is no plate tilt.

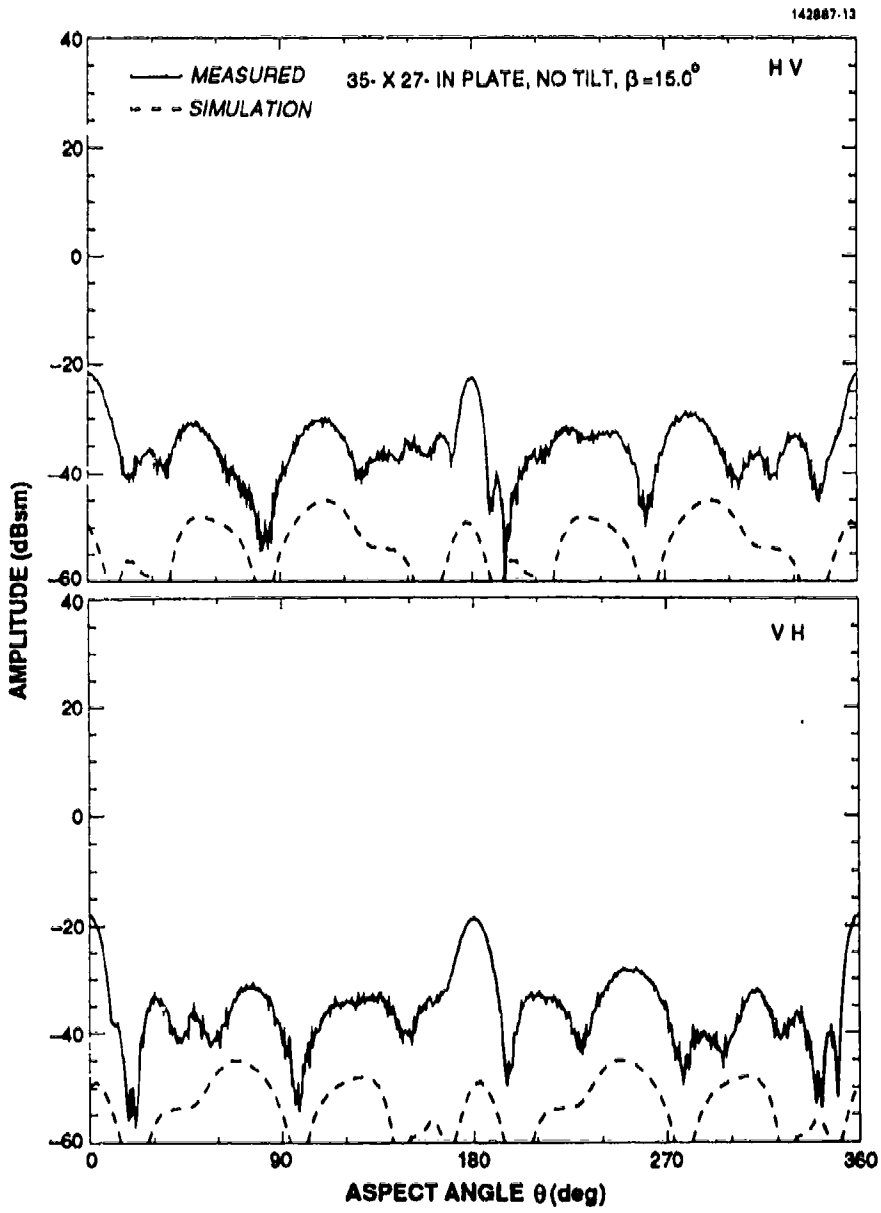


Figure 3-11. Comparison of ESP-4 simulations and measurements of the cross-polarized (HV, VH) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 15°$ and there is no plate tilt.

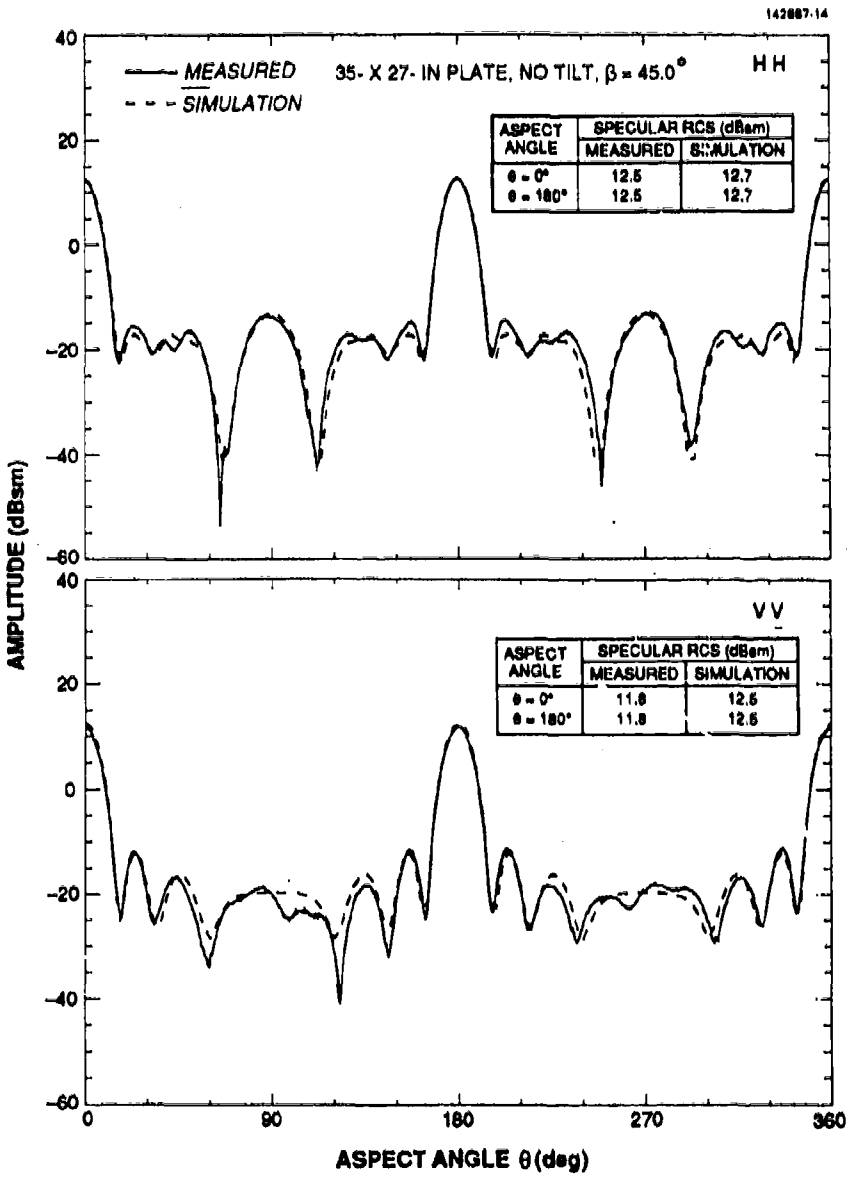


Figure 3-12. Comparison of ESP-4 simulations and measurements of the copolarized (HH, VV) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 45°$ and there is no plate tilt.

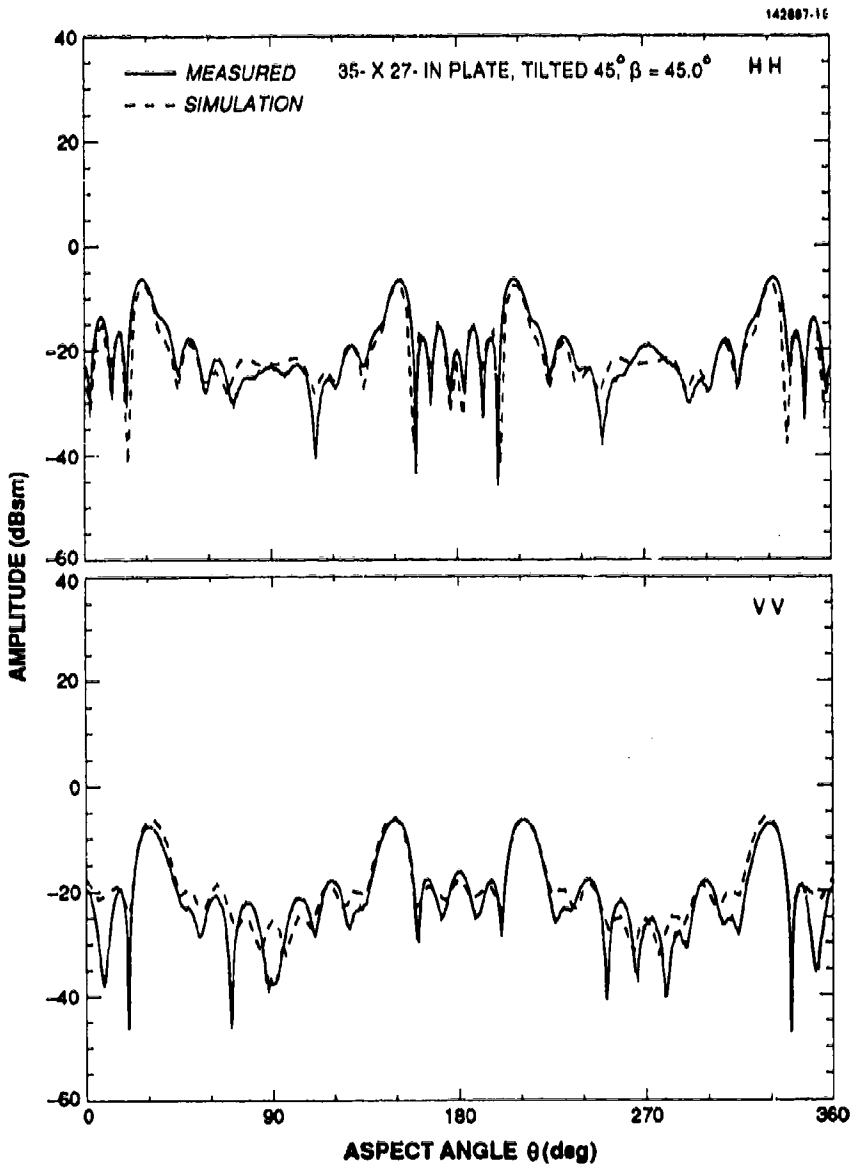


Figure 3-13. Comparison of ESP-4 simulations and measurements of the copolarized (HH, VV) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 45°$ and the plate is tilted 45°.

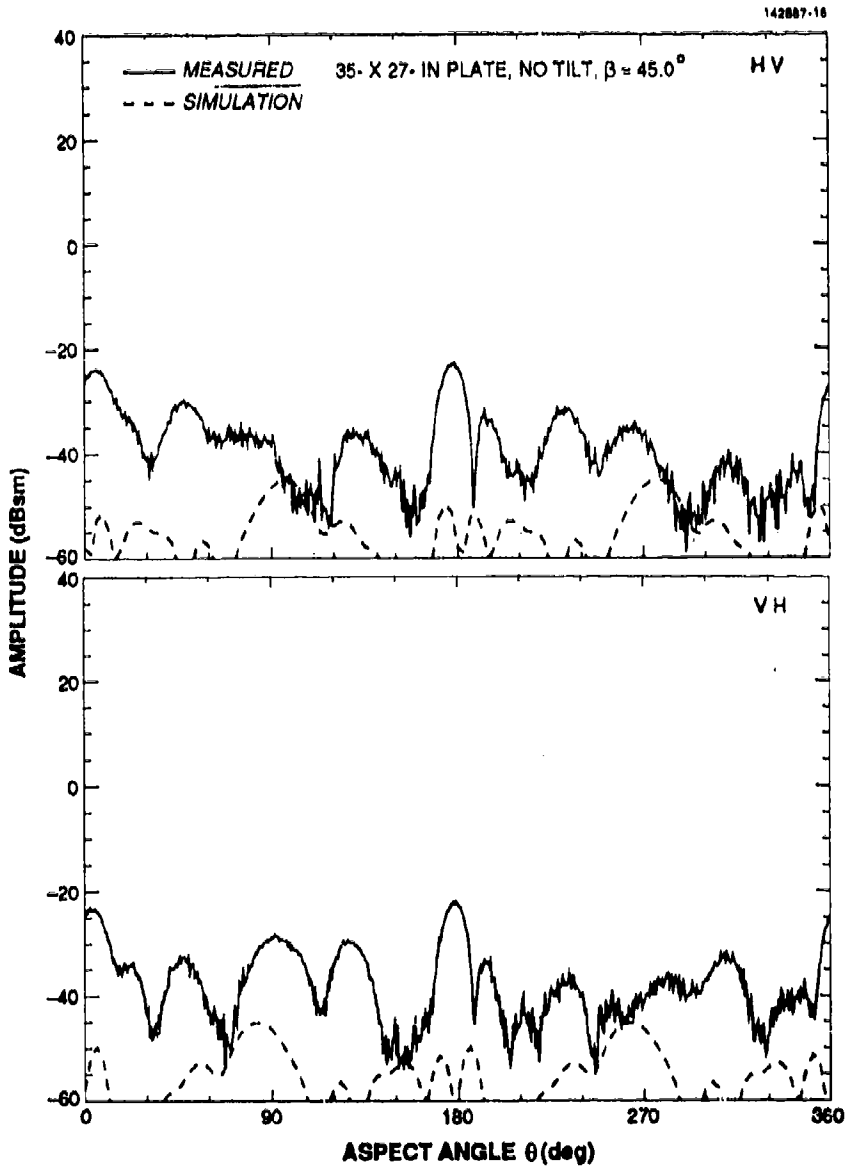


Figure 3-14. Comparison of ESP-4 simulations and measurements of the cross-polarized (HV, VH) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 45°$, and there is no plate tilt.

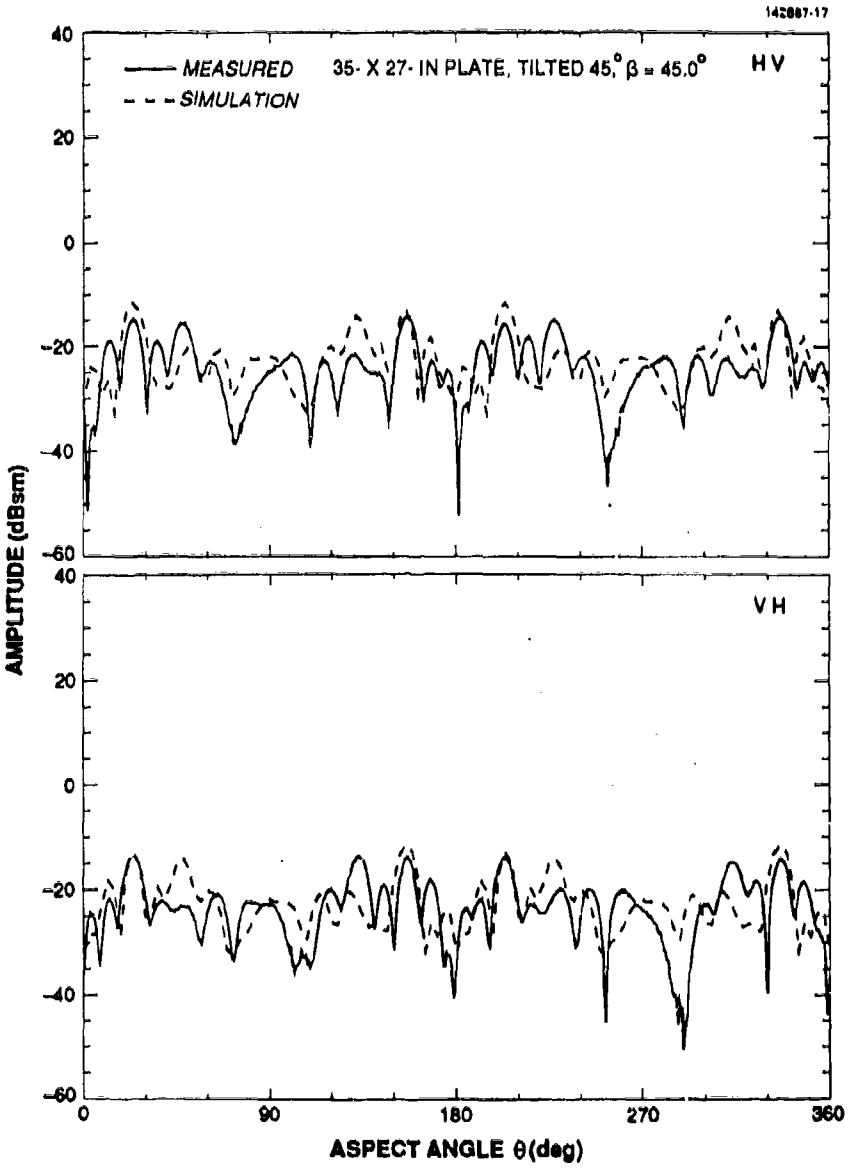


Figure 3-15. Comparison of ESP-4 simulations and measurements of the cross-polarized (HV, VH) bistatic RCS for the 35- × 27-in inch plate at 1.3 GHz. The bistatic angle is $\beta = 45^{\circ}$, and the plate is tilted 45°.

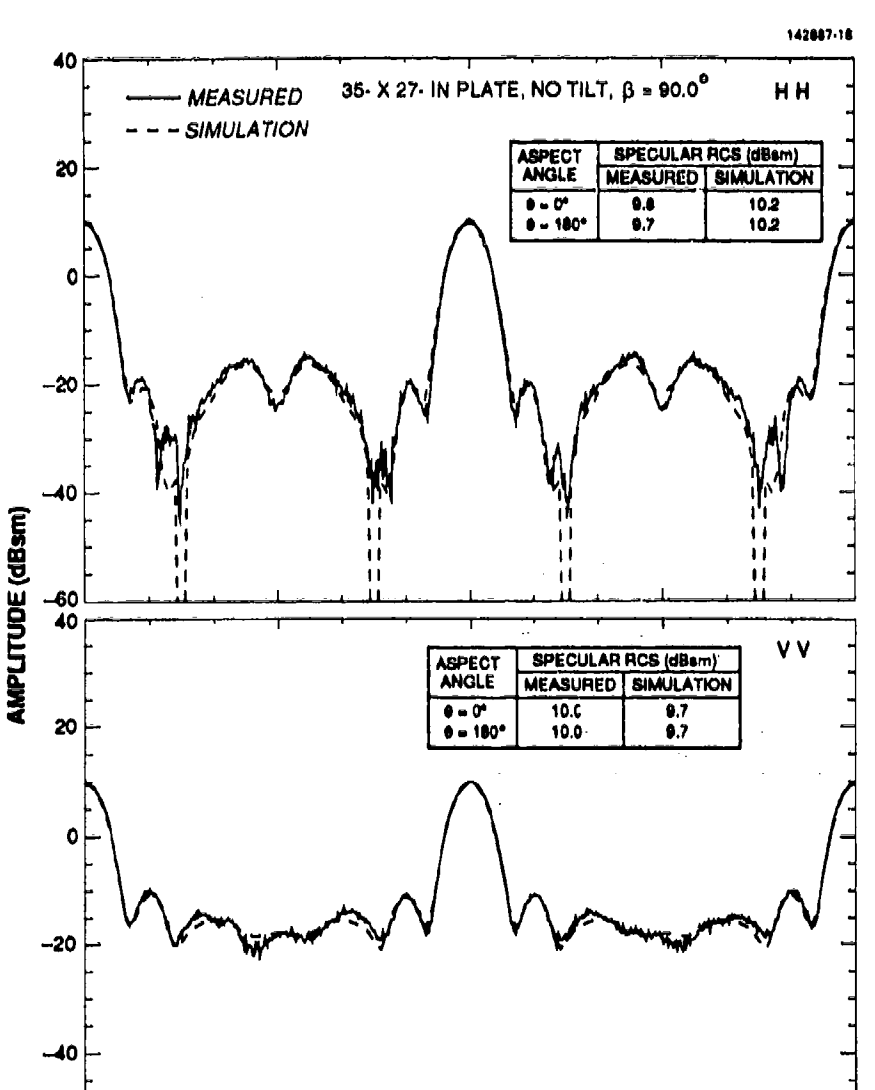


Figure 3-16. Comparison of ESP-4 simulations and measurements of the copolarized (HH, VV) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 90°$, and there is no plate tilt.

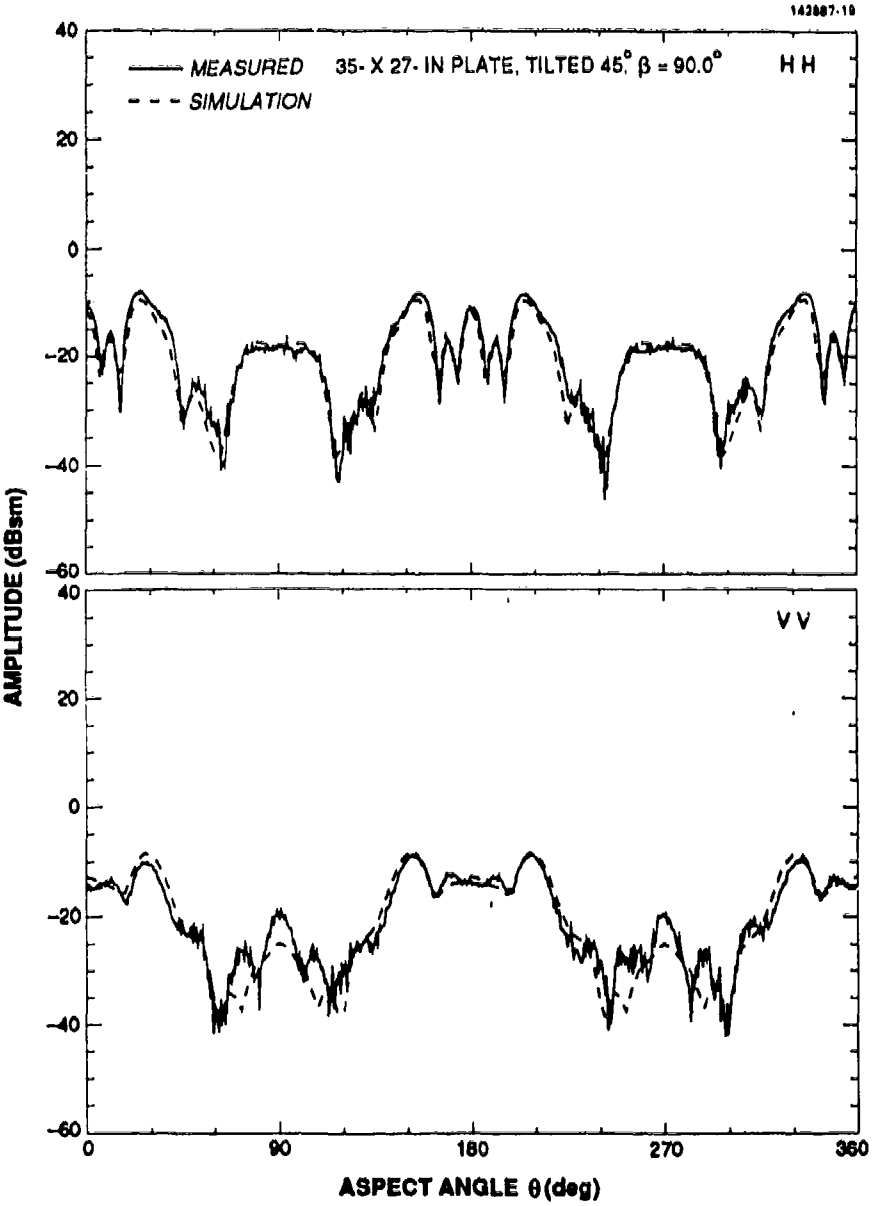


Figure 3-17. Comparison of ESP-4 simulations and measurements of the copolarized (HH, VV) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 90°$, and the plate is tilted 45°.

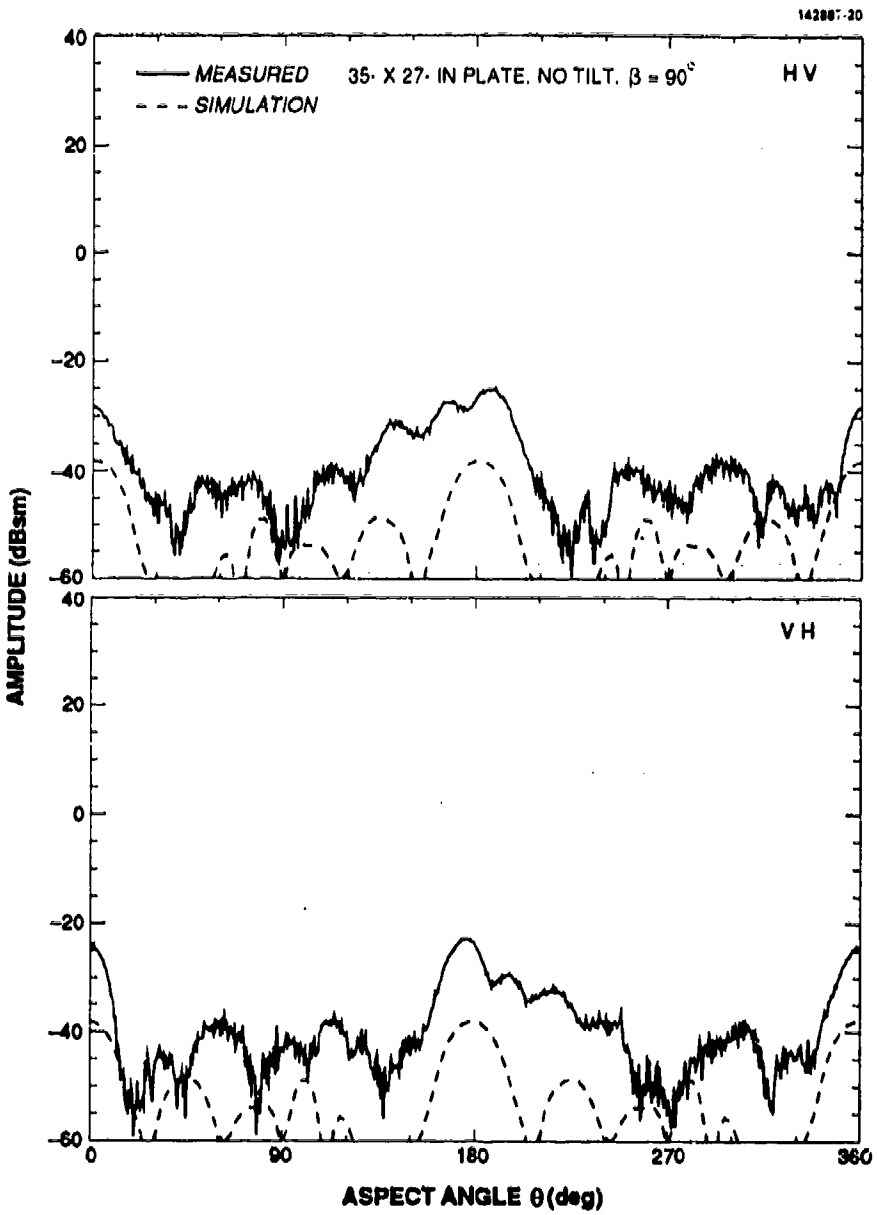


Figure 3-18. Comparison of ESP-4 simulations and measurements of the cross-polarized (HV, VH) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 90°$, and there is no plate tilt.

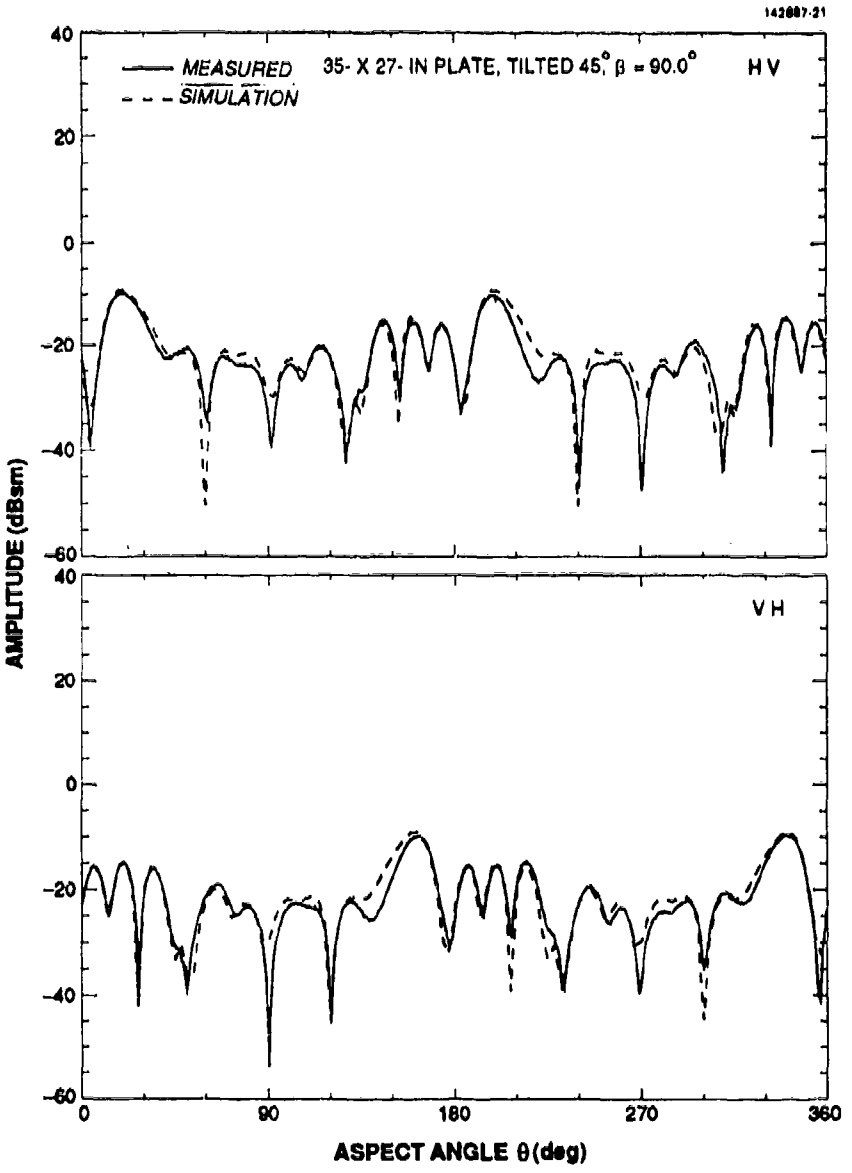


Figure 3-19. Comparison of ESP-4 simulations and measurements of the cross-polarized (HV, VH) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 90°$, and the plate is tilted 45°.

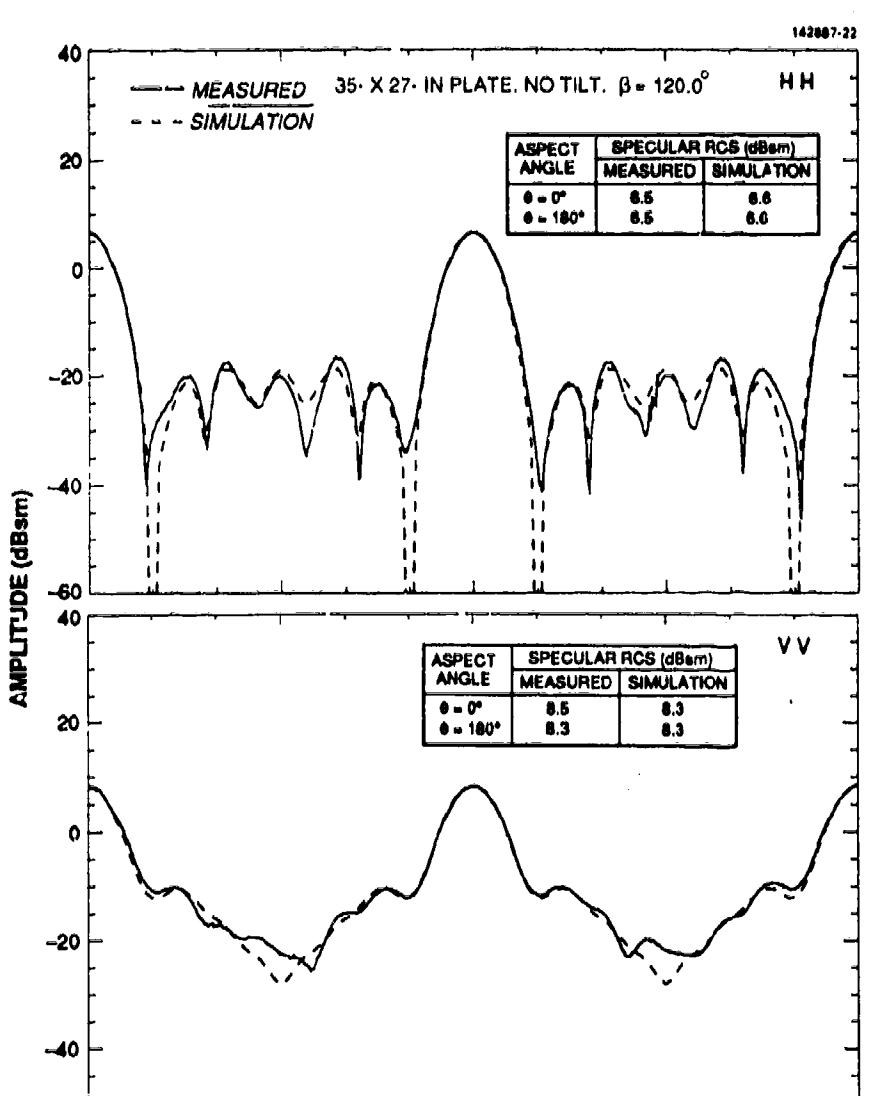


Figure 3-20. Comparison of ESP-4 simulations and measurements of the copolarized (HH, VV) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 120°$, and there is no plate tilt.

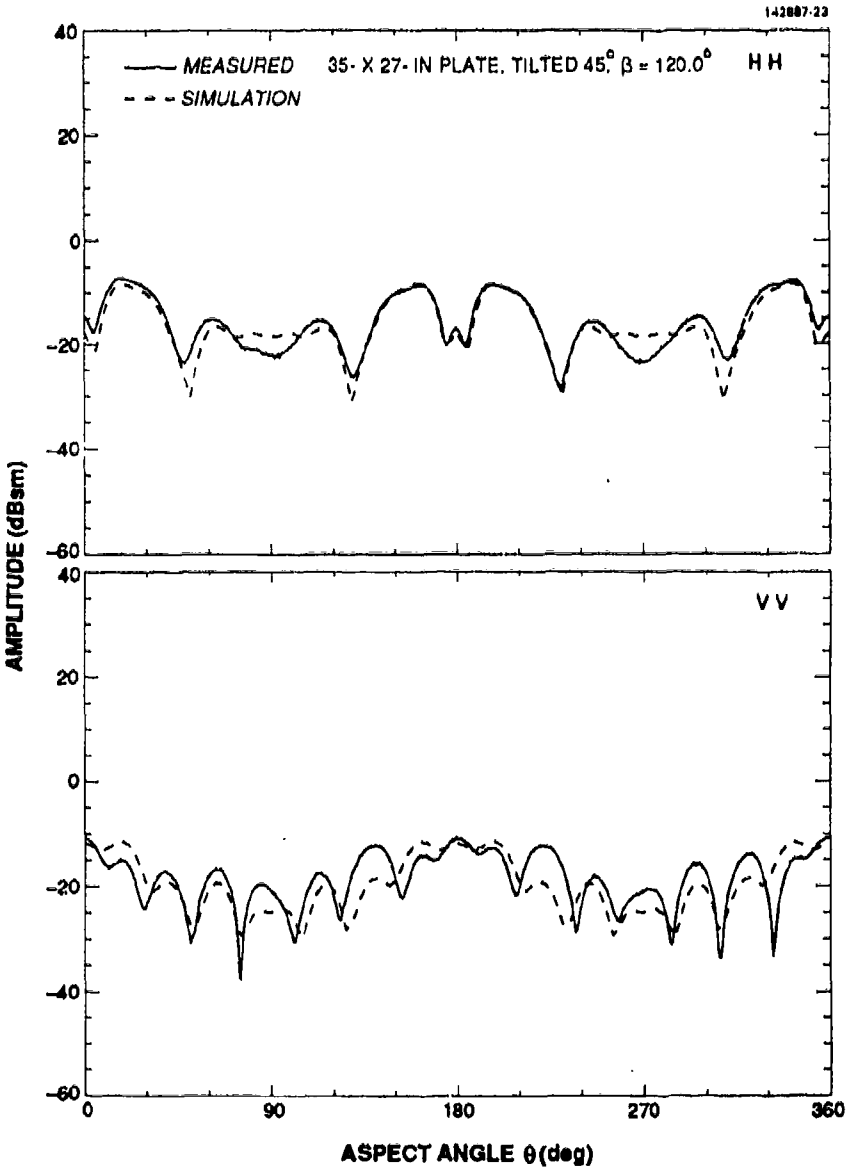


Figure 3-21. Comparison of ESP-4 simulations and measurements of the copolarized (HH, VV) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 120°$, and the plate is tilted 45°.

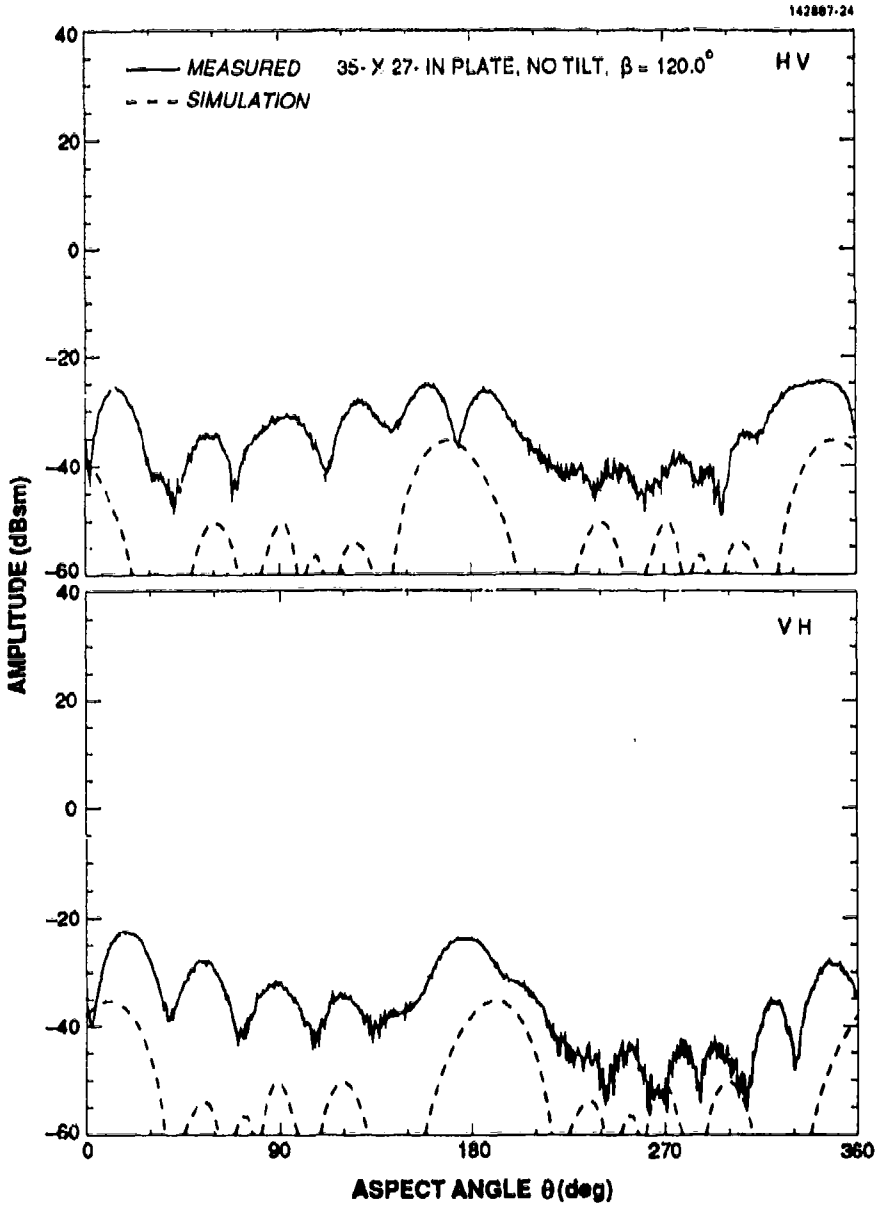


Figure 3-22. Comparison of ESP-4 simulations and measurements of the cross-polarized (HV, VH) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 120°$, and there is no plate tilt.

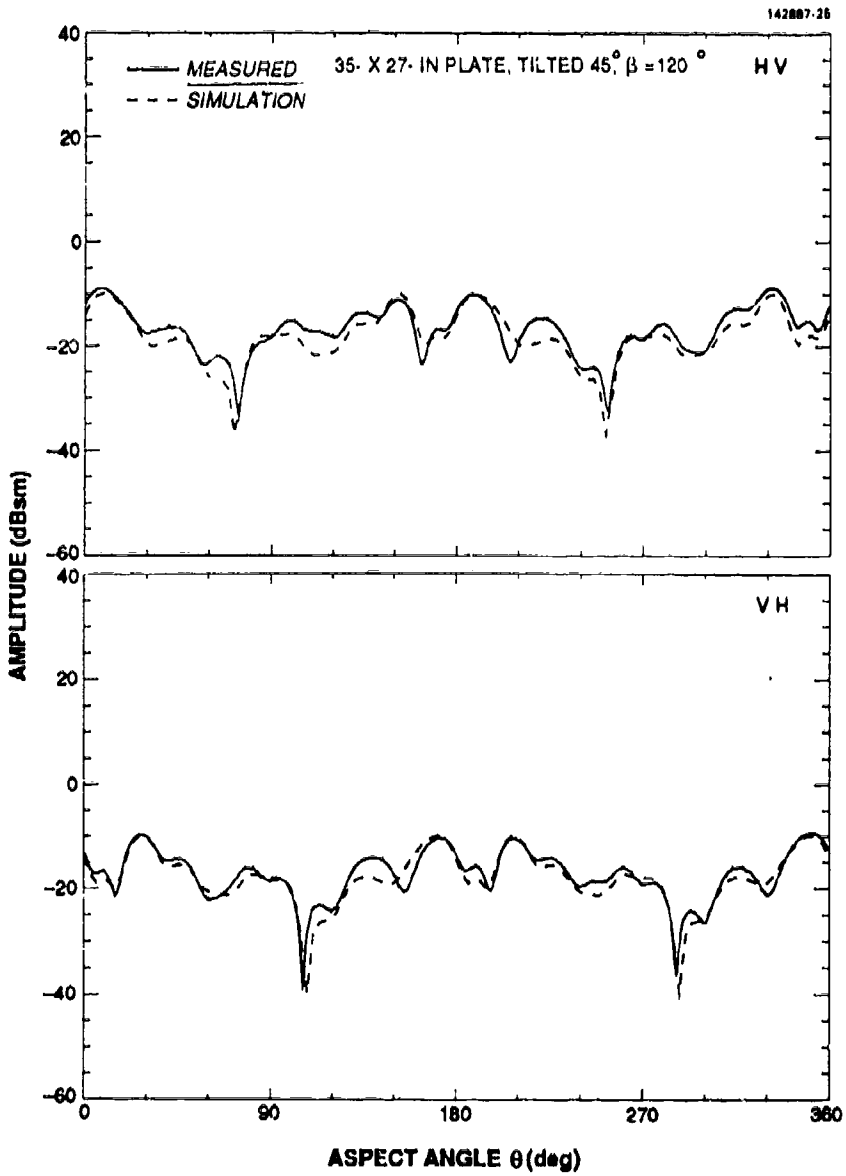


Figure 3-23. Comparison of ESP-4 simulations and measurements of the cross-polarized (HV, VH) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 120°$, and the plate is tilted 45°.

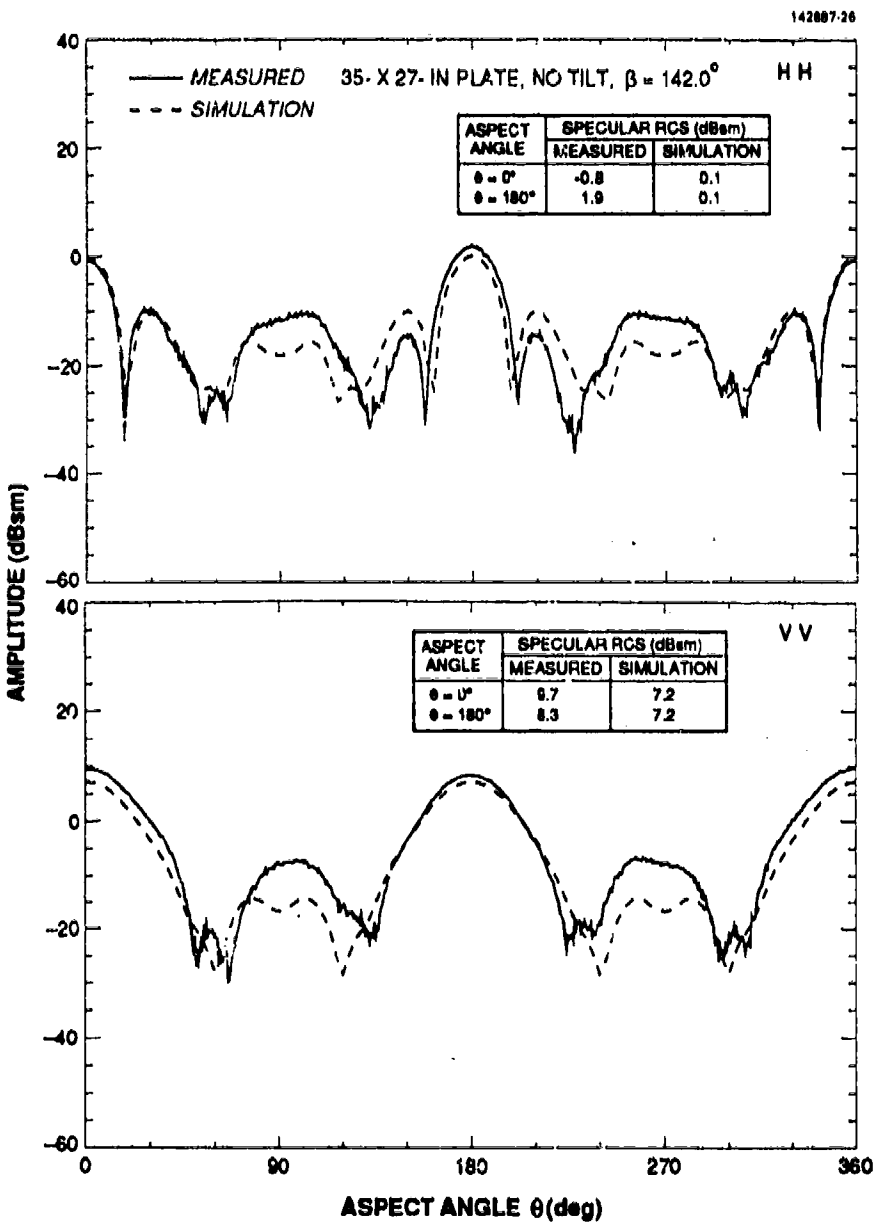


Figure 3-24. Comparison of ESP-4 simulations and measurements of the copolarized (HH, VV) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 142°$, and there is no plate tilt.

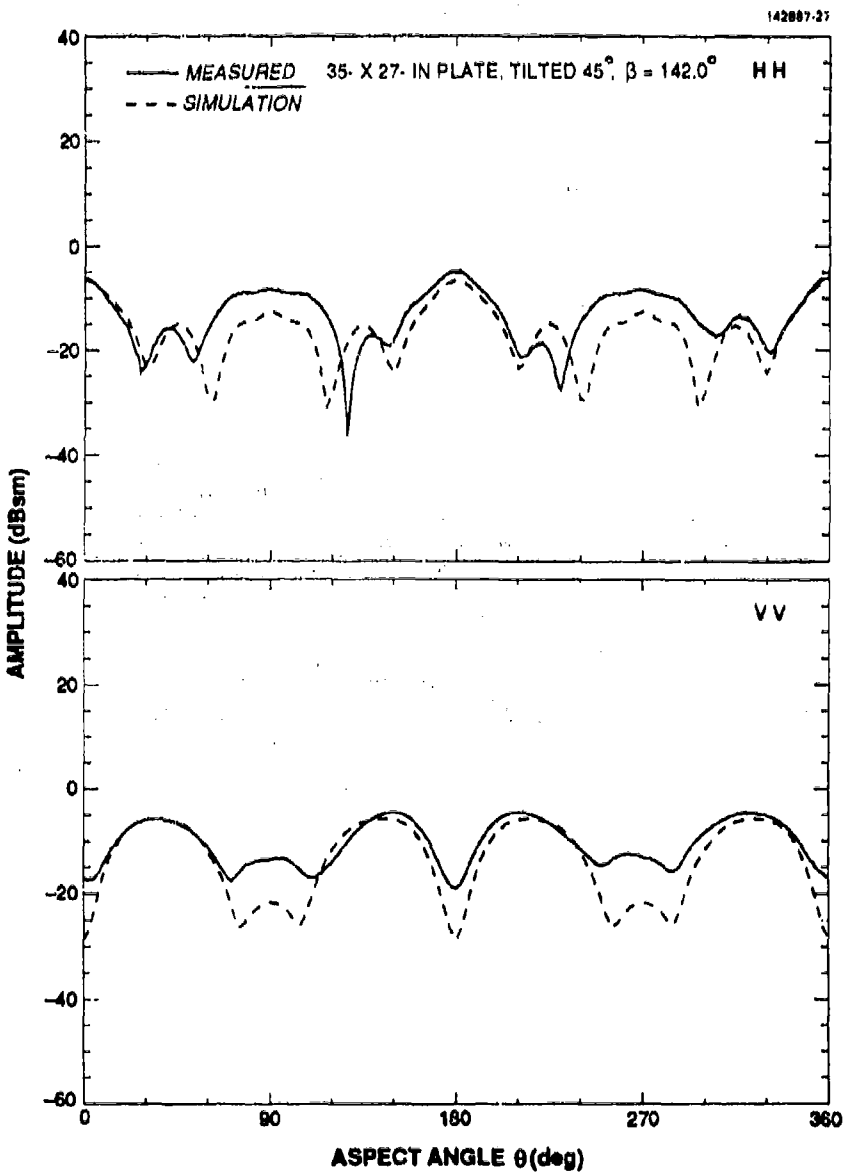


Figure 3-25. Comparison of ESP-4 simulations and measurements of the copolarized (HH, VV) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 142°$, and the plate is tilted 45°.

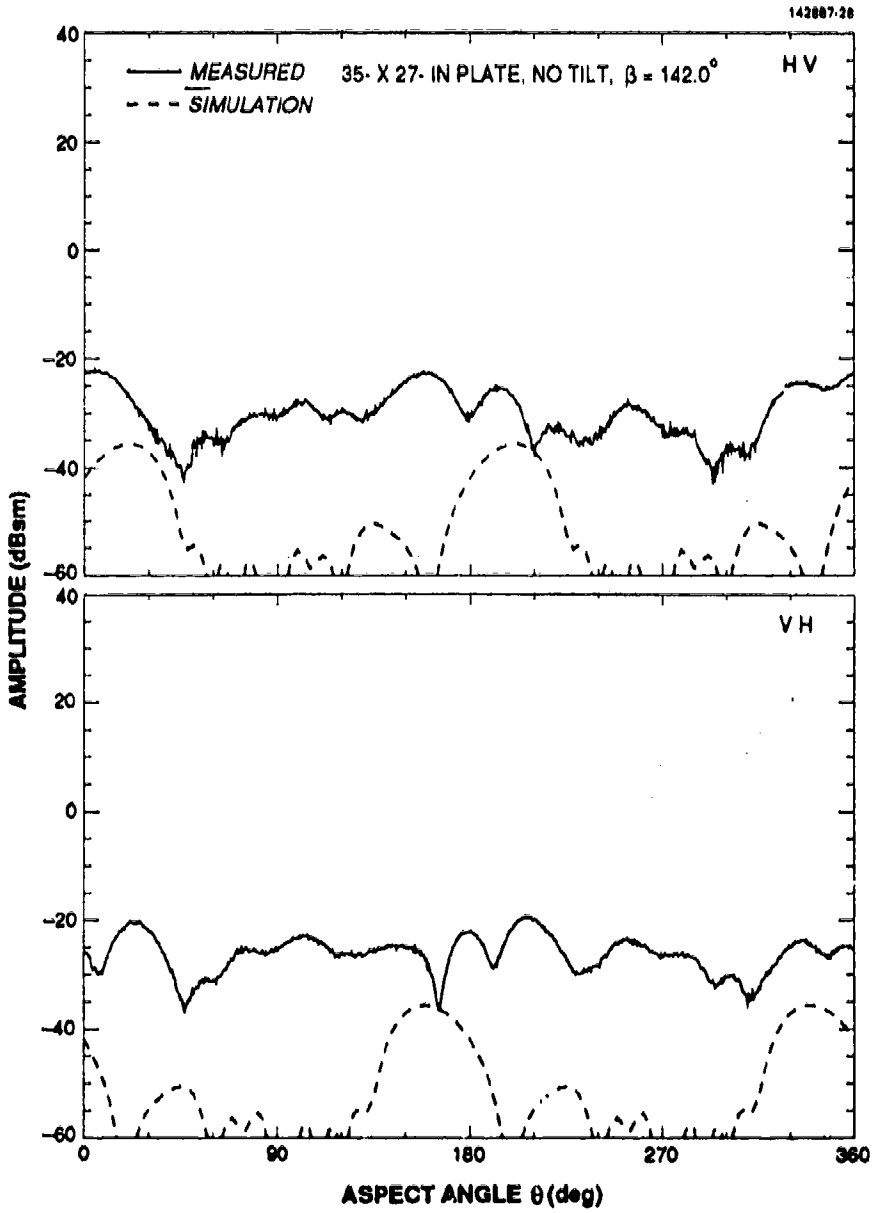


Figure 3-26. Comparison of ESP-4 simulations and measurements of the cross-polarized (HV VH) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 142°$, and there is no plate tilt.

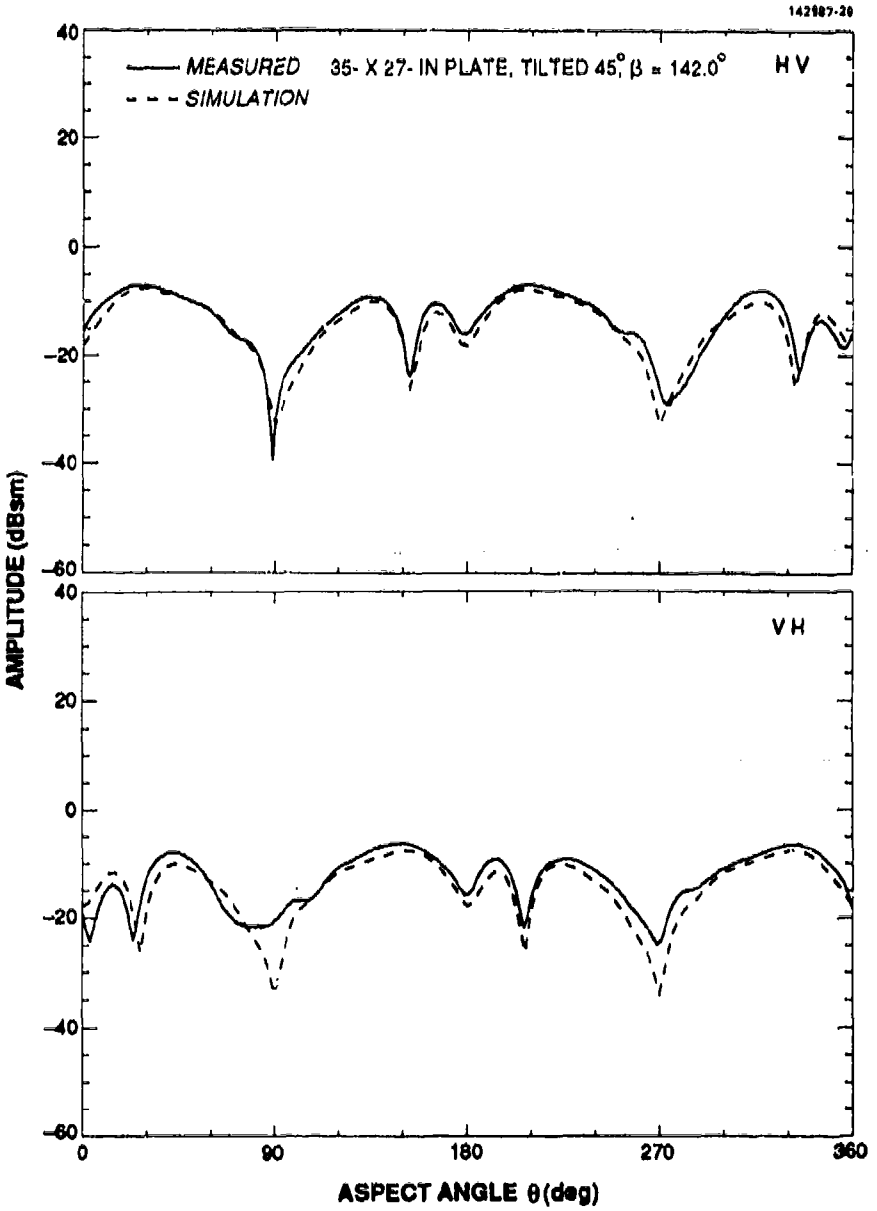


Figure 3-27. Comparison of ESP-4 simulations and measurements of the cross-polarized (HV, VH) bistatic RCS for the 35- × 27-in plate at 1.3 GHz. The bistatic angle is $\beta = 142°$, and the plate is tilted 45°.

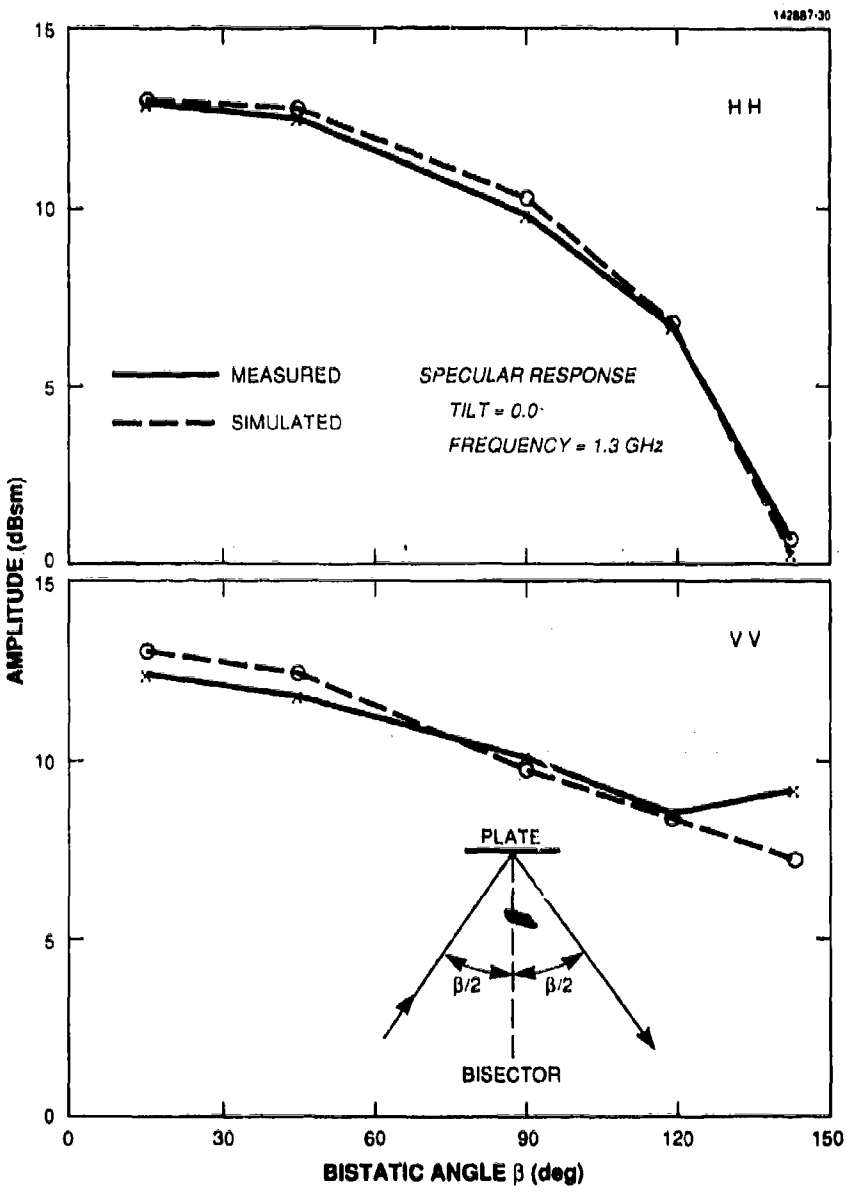


Figure 3-28. Comparison of ESP-4 simulations and measurements of the specular copolarized (HH, VV) bistatic RCS for the 35- × 27-in plate at 1.3 GHz.

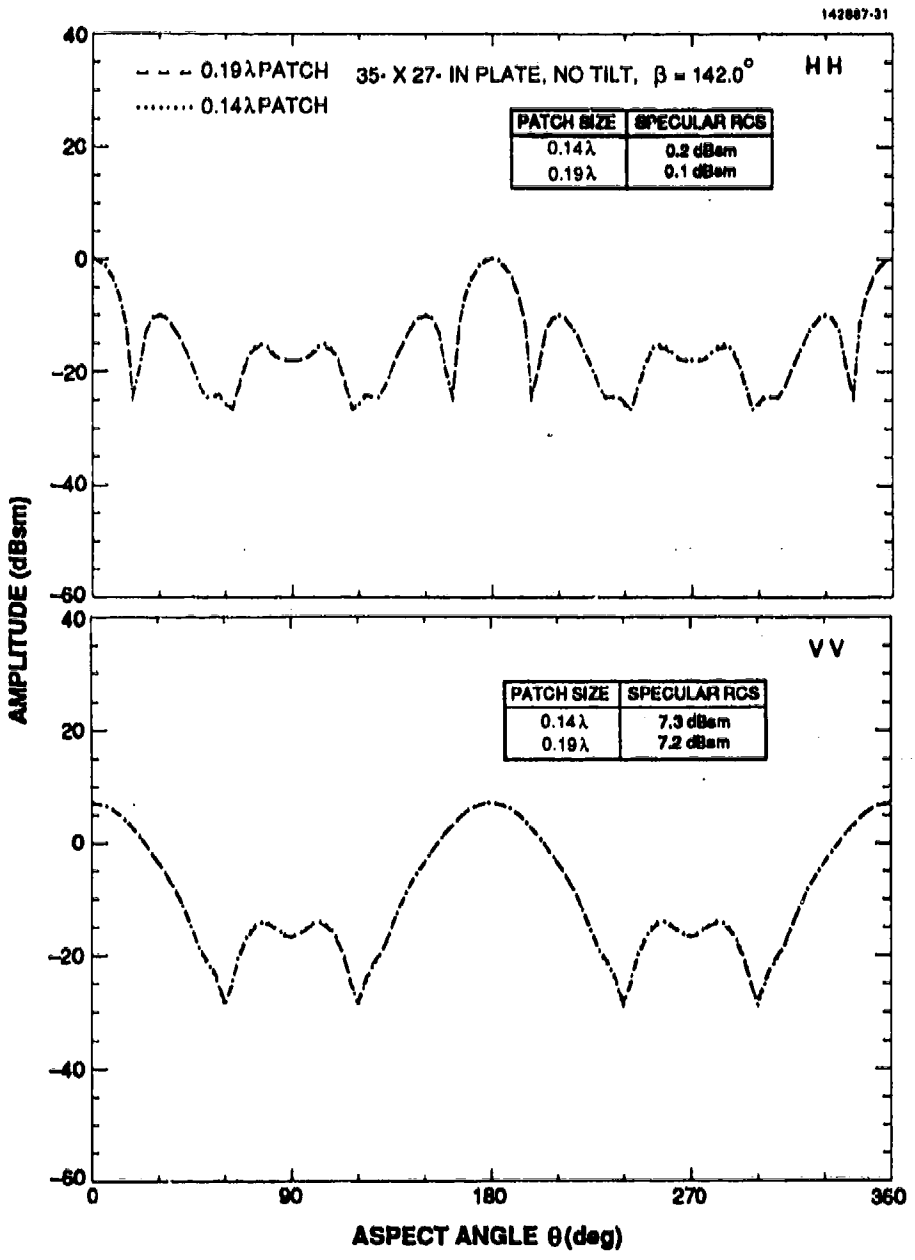


Figure 3-29. Convergence check of ESP-4 simulations. The figure shows the copolarized (HH, VV) bistatic RCS for the 35- × 27-in plate at 1.3 GHz with two different surface patch sizes. The bistatic angle is $\beta = 142°$, and there is no plate tilt.

4. CONCLUSION

This report has described modifications made at Lincoln Laboratory to The Ohio State University electromagnetic surface patch code version 4 (ESP-4) and its utilization in the computation of the bistatic radar cross section of a rhombus-shaped flat plate. The modifications are the restructuring of the input data statements and the addition of a new option for bistatic radar cross section computation with a fixed bistatic angle. A listing of the revised software is given in the appendix.

Comparisons of the ESP-4 method of moments simulations with far-field measurements over bistatic angles 15° to 142° have been made at 1.3 GHz for a 35- × 27-in rhombus plate in untilted and tilted configurations and good agreement is observed. From these simulations, it is concluded that both the copolarized and cross-polarized bistatic RCS of arbitrarily oriented flat plates can be accurately predicted with this software.

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APPENDIX A
REVISED ESP-4 SOFTWARE LISTING

The purpose of this appendix is to list the main program of a modified version of the electromagnetic surface patch code (ESP-4). This software was obtained in July 1988 from The Ohio State University and has since been modified at Lincoln Laboratory. The important modifications are the addition of namelist input data and the option for bistatic radar cross section calculation with a fixed bistatic angle and variable target rotation. Other minor changes to the code are documented with comments in the modified ESP-4 code listed below. The main program contains nearly 1700 lines of code and is listed in its entirety. The ESP-4 subroutines contain an additional 7000 lines of code and are not listed here. However, in the subroutines no changes other than a global conversion from (ARCOS, ARSIN, ARTAN) to (ACOS, ASIN, ATAN) have been made. Following the listing are two data files corresponding to the untilted and tilted plate configurations.

```
*****Modified ESP-4 FORTRAN 77 code listing (SUN 3 computer system).
****Main program      Filename:   esp4nam.f   at Lincoln Laboratory
C                                                                       ESP00010
C                                                                       ESP00020
C       OHIO STATE UNIVERSITY ELECTROSCIENCE LAB MOMENT METHOD, SURFACE ESP00030
C       PATCH CODE.  BASED UPON PIECEWISE SINUSOIDAL REACTION           ESP00040
C       FORMULATION. TREATS:                                            ESP00050
C          THIN WIRES                                                   ESP00060
C          RECTANGULAR OR POLYGONAL PLATES                              ESP00070
C          WIRE/PLATE ATTACHMENTS (AT LEAST 0.1*WAVE FROM EDGE)         ESP00080
C          PLATE/PLATE ATTACHMENTS                                      ESP00090
C          OPEN OR CLOSED SURFACES                                      ESP00100
C                                                                       ESP00110
C       REFERENCE "A USER'S MANUAL FOR AN ELECTROMAGNETIC SURFACE
C       PATCH CODE: ESP VERSION IV," BY E.H. NEWMAN, OSU/ESL REPORT
C       716199-11, AUGUST 1988.
C
C       ALSO "A USER'S MANUAL FOR ELECTROMAGNETIC SURFACE PATCH CODE:   ESP00120
C       VERSION III - POLYGONAL PLATES AND WIRES" BY E.H. NEWMAN AND    ESP00130
C       R.L. DILSAVOR    OSU/ESL REPORT 716148-19, APRIL 1987.          ESP00140
C                                                                       ESP00150
C       ANY COMMENTS CAN BE REFERRED TO:                                ESP00160
C                                                                       ESP00170
C       EDWARD H. NEWMAN                                                ESP00180
C       ELECTROSCIENCE LABORATORY                                       ESP00190
C       1320 KINNEAR ROAD                                               ESP00200
C       COLUMBUS, OHIO 43212                                            ESP00210
C       PHONE: (614) 292-4999                                           ESP00220
C                                                                       ESP00230
C   FILENAME esp4nam.f  SUN 3 COMPUTER SYSTEM at MIT LINCOLN LABORATORY.
C                       MODIFIED FOR NAMELIST INPUT DATA AND FIXED
C                       BISTATIC ANGLE WITH VARIABLE TARGET ROTATION.
C                       ALL LINCOLN LABORATORY MODIFICATIONS ARE
C                       MADE EVIDENT BY THE ABSENCE OF ESP LINE NUMBERS.
C                       THE SUBROUTINES USED BY esp4nam.f HAVE BEEN
C                       DIVIDED INTO TWO FILES esp4subs1.f AND
C                       esp4subs2.f WHICH ARE THE ORIGINAL ESP4
C                       SUBROUTINES (I.E. NO MODIFICATIONS).
C   DATE: 3 JANUARY 1990
C                                                                       ESP00250
C                                                                       ESP00260
C                                                                       ESP00270
C       DIMENSION INDICATORS:                                           ESP00280
C       THE FOLLOWING ARE DEFINED BY THE USER:                          ESP00290
C                                                                       ESP00300
C       IDFIL: INDICATOR TO DIMENSION FOR FILAMENT TESTING              ESP00310
C            = 1 IMPLIES DIMENSION FOR FILAMENT TESTING                 ESP00320
C            = 0 IMPLIES DO NOT DIMENSION FOR FILAMENT TESTING          ESP00330
C       IDSUR: INDICATOR TO DIMENSION FOR FULL SURFACE TESTING          ESP00340
C            = 1 IMPLIES DIMENSION FOR FULL SURFACE TESTING             ESP00350
C            = 0 IMPLIES DO NOT DIMENSION FOR FULL SURFACE TESTING      ESP00360
C       IDWR= MAX. NUMBER OF WIRE POINTS, WIRE SEGMENTS, AND WIRE MODES ESP00370
C       IPL= MAX. NUMBER PLATES                                         ESP00380
C       ICN= MAX. NUMBER OF CORNERS ON POLYGONAL PLATES                 ESP00390
C       IAT= MAX. NUMBER WIRE/PLATE ATTACHMENT POINTS                   ESP00400
C       ITOT= MAX. TOTAL NUMBER OF MODES (WIRE+PLATE+ATTCH.)            ESP00410
C       IDMZI = INDICATOR FOR MAKING FREQUENCY SWEEP COMPUTATION        ESP00420
C            = 1 IMPLIES SET UP Z ARRAY FOR INTERPOLATION               ESP00430
C            = 0 NO FREQUENCY SWEEP                                     ESP00440
C       IERVSR = MAX. I FOR THE ERVSR(IAT,I) ARRAY USED IN SUB. ZTOTZ   ESP00450
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C                                                                       ESP00460
C       THE FOLLOWING ARE COMPUTED BY THE CODE:                         ESP00470
C                                                                       ESP00480
C       IDZT= MAX. LENGTH OF 1-D IMPEDANCE ARRAY ZT                     ESP00490
C       IDZTF=MAX. INDICATOR FOR 2-D ARRAY ZTF USED FOR FILAMENT TESTINGESP00500
C       IDWR2= 2*IDWR                                                   ESP00510
C       ITW2= THE LARGER OF IDWR2 AND ITOT                              ESP00520
C                                                                       ESP00530
C       DEFINE DIMENSION INDICATORS                                     ESP00540
C                                                                       ESP00550
        PARAMETER (IDFIL=1)                                             ESP00560
        PARAMETER (IDSUR=1)                                             ESP00570
        PARAMETER (IDWR=30)                                             ESP00580
        PARAMETER (IPL=20)                                              ESP00590
        PARAMETER (ICN=8)                                               ESP00600
        PARAMETER (IAT=4)                                               ESP00610
C       PARAMETER (ITOT=200)                                            ESP00620
        PARAMETER (ITOT=500)
        PARAMETER (IDMZI = 1)                                           ESP00630
        PARAMETER (IERVSR = 200)                                        ESP00640
C****THE FOLLOWING LINE ADDED FOR NAMELIST MODIFICATION
      PARAMETER (INFPT=50)
C                                                                       ESP00650
C       THE FOLLOWING IS EQUIVALENT TO:                                 ESP00660
C       PARAMETER (IDZT=MAXO((IDWR**2+IDWR)/2,IDSUR*(ITOT**2+ITOT)/2,1))ESP00670
C                                                                       ESP00680
        PARAMETER (NUM1=1+(IDWR**2+IDWR)/2)                             ESP00690
        PARAMETER (NUM2=1+IDSUR*(ITOT**2+ITOT)/2)                       ESP00700
        PARAMETER (MLT1=(((NUM1/NUM2)*NUM2)/(1.0*NUM1))+0.99999)        ESP00710
        PARAMETER (MLT2=(((NUM2/NUM1)*NUM1)/(1.0*NUM2))+0.99999)        ESP00720
        PARAMETER (NUM3=1-1+(MLT1*NUM1+MLT2*NUM2)/(MLT1+MLT2))          ESP00730
        PARAMETER (NUM4=1+1)                                            ESP00740
        PARAMETER (MLT3=(((NUM3/NUM4)*NUM4)/(1.0*NUM3))+0.99999)        ESP00750
        PARAMETER (MLT4=(((NUM4/NUM3)*NUM3)/(1.0*NUM4))+0.99999)        ESP00760
        PARAMETER (IDZT=-1+(MLT3*NUM3+MLT4*NUM4)/(MLT3+MLT4))           ESP00770
C                                                                       ESP00780
C       THE FOLLOWING IS EQUIVALENT TO:                                 ESP00790
C       PARAMETER (IDZTF=MAXO(IDFIL*ITOT,1))                            ESP00800
C                                                                       ESP00810
        PARAMETER (NUM5=1+IDFIL*ITOT)                                   ESP00820
        PARAMETER (NUM6=1+1)                                            ESP00830
        PARAMETER (MLT5=(((NUM5/NUM6)*NUM6)/(1.0*NUM5))+0.99999)        ESP00840
        PARAMETER (MLT6=(((NUM6/NUM5)*NUM5)/(1.0*NUM6))+0.99999)        ESP00850
        PARAMETER (IDZTF=-1+(MLT5*NUM5+MLT6*NUM6)/(MLT5+MLT6))          ESP00860
C                                                                       ESP00870
        PARAMETER (IDWR2=2*IDWR)                                        ESP00880
C                                                                       ESP00890
C       THE FOLLOWING IS EQUIVALENT TO:                                 ESP00900
C       PARAMETER (ITW2=MAXO(ITOT,IDWR2))                               ESP00910
C                                                                       ESP00920
        PARAMETER (NUM7=1+ITOT)                                         ESP00930
        PARAMETER (NUM8=1+IDWR2)                                        ESP00940
        PARAMETER (MLT7=(((NUM7/NUM8)*NUM8)/(1.0*NUM7))+0.99999)        ESP00950
        PARAMETER (MLT8=(((NUM3/NUM7)*NUM7)/(1.0*NUM8))+0.99999)        ESP00960
        PARAMETER (ITW2=-1+(MLT7*NUM7+MLT8*NUM8)/(MLT7+MLT8))           ESP00970
C                                                                       ESP00980
C       IDMI = 1 IF IDMZI = 0                                           ESP00990
C            = 3 IF IDMZI = 1                                           ESP01000
        PARAMETER (IDMI=1+IDMZI*2)                                      ESP01010
        PARAMETER (IDZTI=1+IDMZI*IDZT)                                  ESP01020
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      PARAMETER (IDZTFI=1+IDMZI*IDZTF)                                  ESPO1030
C                                                                       ESPO1040
C                                                                       ESPO1050
C     THE FOLLOWING ARE DIMENSIONED BY IDWR:                            ESPO1060
C                                                                       ESPO1070
      COMPLEXCGD(IDWR),SGD(IDWR)                                        ESPO1080
      DIMENSIOND(IDWR),IA(IDWR),IB(IDWR),ND(IDWR),ISC(IDWR),MD(IDWR,4)  ESPO1090
      DIMENSIONI1(IDWR),I2(IDWR),I3(IDWR),JA(IDWR),JB(IDWR)             ESPO1100
      DIMENSIONX(IDWR),Y(IDWR),Z(IDWR)                                  ESPO1110
C                                                                       ESPO1120
C     THE FOLLOWING ARE DIMENSIONED BY IDWR2 = 2*IDWR:                  ESPO1130
C                                                                       ESPO1140
      COMPLEXZLD(IDWR2),VG(IDWR2)                                       ESPO1150
C                                                                       ESPO1160
C     THE FOLLOWING ARE DIMENSIONED BY THE LARGER OF ITOT OR IDWR2:     ESPO1170
C                                                                       ESPO1180
      COMPLEXCG(ITW2)                                                   ESPO1190
C                                                                       ESPO1200
C     THE FOLLOWING ARE DIMENSIONED BY IPL AND ICN:                     ESPO1210
C                                                                       ESPO1220
      DIMENSIONNM12N(IPL),NM23N(IPL),IPN(IPL),PCN(3,ICN,IPL)            ESPO1230
     DIMENSION XP(ICN),YP(ICN),ZP(ICN)
      DIMENSIONNCNRS(IPL),SEGM(IPL),PC(3,ICN),NPL11(IPL),NDNPLT(IPL)    ESPO1240
      DIMENSION NPL22(IPL),IREC(IPL),SUBI(IPL),IGS(IPL)                 ESPO1250
      COMPLEX ZSHT(IPL),ZSHTF(IPL)                                      ESPO1260
C                                                                       ESPO1270
C     THE FOLLOWING ARE DIMENSIONED BY IAT AND IERVSR:                  ESPO1280
C                                                                       ESPO1290
     INTEGER NASAT(IAT),IABAT(IAT)
      DIMENSIONEDSK(IAT),RMIN(IAT),DR(IAT),NPLA(IAT),NSA(IAT),          ESPO1300
     2 PDIST(IAT)                                                       ESPO1310
      COMPLEXERVSR(IAT,IERVSR),ZLDA(IAT),VGA(IAT)                       ESPO1320
C                                                                       ESPO1330
C     THE FOLLOWING ARE DIMENSIONED BY ITOT:                            ESPO1340
C                                                                       ESPO1350
      DIMENSIONPA(ITOT,4,3),PB(ITOT,4,3),IQUAD(ITOT)                    ESPO1360
      DIMENSIONIOVT(ITOT,4),DOVL(ITOT),ITK(ITOT),OVEP(ITOT,3,2)         ESPO1370
      COMPLEXCJ(ITOT),CJP(ITOT),CJT(ITOT),ETT(ITOT),EPP(ITOT),V(ITOT)   ESPO1380
      COMPLEX EXN(ITOT),EYN(ITOT),EZN(ITOT)                             ESPO1390
      DIMENSION MPLA(ITOT),MPLB(ITOT),PSZ(ITOT)                         ESPO1400
C                                                                       ESPO1410
C     THE FOLLOWING ARE DIMENSIONED BY INFPT  ****NAMELIST DATA***
     INTEGER IFMM(INFPT),IABB(INFPT)
     COMPLEX VLGG(INFPT),ZLL(INFPT)
C
C     THE FOLLOWING ARE DIMENSIONED BY IDZT:                            ESPO1420
C                                                                       ESPO1430
      COMPLEXZT(IDZT)                                                   ESPO1440
C                                                                       ESPO1450
C     THE FOLLOWING ARE DIMENSIONED BY IDZTF:                           ESPO1460
C                                                                       ESPO1470
      COMPLEX ZTF(IDZTF,IDZTF)                                          ESPO1480
C                                                                       ESPO1490
C     THE FOLLOWING ARRAYS HOLD THE Z MATRICES FOR THE FREQ. SWEEP      ESPO1500
C                                                                       ESPO1510
      COMPLEX ZTIN(IDMI,IDZTI),ZTFIN(IDMI,IDZTFI,IDZTFI)                ESPO1520
C                                                                       ESPO1530
C     THE FOLLOWING ARE FIXED DIMENSIONED:                              ESPO1540
C                                                                       ESPO1550
      DIMENSION IZC(3)                                                  ESPO1560
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        COMPLEXETE(1441),EPE(1441),ERE(1441),ETAZ(1441),                ESP01670
     2  EPAZ(1441)                                                      ESP01680
        DIMENSION PET(1441),PEP(1441),PER(1441)                         ESP01690
        COMPLEX ERAZ(1441)                                              ESP01600
        COMPLEXETA,GAM,Z11,Y11,ERRS,ETTS,EPPS,ETPS,EPTS,ZS,ZL,VLG,EGD   ESP01610
        COMPLEX ZIN,YIN,VIN                                             ESP01620
        COMPLEXCGA,CGB,CGCN,CEXP1,CEXP2,CEXP3,CEXPK,FAC1,FAC2,FAC3,FACK ESP01630
        COMPLEX EXT,EYT,EZT,EXP,EYP,EZP,ETRS,EPRS,XJ,YSHT,YSHTF         ESP01640
      COMMON /A/ WV,PI,A,Q,GAM,ETA,XK                                   ESP01650
C***ADDITION OF NAMELISTS
      NAMELIST /RNCTRL/NGO,NPRINT,NRUNS,NWGS,IWR,IWRZT,INT,INTP,INTD,
     2INWR,IRGM,IFIL,RF,INDZI
      NAMELIST /FSWEEP/FMC1,FMC2,DFZI,DFF,IRS12,THRD,PHRD,THRI,PHRI
      NAMELIST /PATTRN/IFE,IPFE,FNDFE,PHFE,IFA,IPFA,FNDFA,THFA,
     2ISE,IPSE,FNDSE,PHSE,THIN,PHIN,ISA,IPSA,FNDSA,THSA,
     3AZRANG,ELRANG,AZMIN,ELMIN,IBISC,BETA,NPTBIS,BANGRG
C**NOTE: AZRANG, ELRANG INCLUDED TO REPLACE FIXED 360 DEG.
C**NOTE: AZMIN,ELMIN INCLUDED TO START PATTERNS AT ARB. POINT
C**NOTE: IBISC=1 USES FIXED BISTATIC ANGLE FEATURE WITH
C        BETA THE BISTATIC ANGLE,
C        NPTBIS THE NUMBER OF TARGET ROTATION ANGLES,
C        BANGRG THE ANGULAR RANGE OF TARGET ROTATION
C        NOTE: BANGRG CAN BE >0 OR <0 TO DETERMINE ROTATION DIRECTION
C**WHEN THE BISTATIC OPTION IS USED, ELRANG AND AZRANG ARE SET=0
      NAMELIST /FWIRET/FMC,CMM,A,NPLTS
      NAMELIST /PLATEG/NCNRS,SEGM,IREC,IPN,IGS,ZSHT,XP,YP,ZP
      NAMELIST /SAVEZ/IWRZM,IRDZM
      NAMELIST /WIREAG/NM,NP,NAT,NFPT,NFS1,NFS2,X,Y,Z,IA,IB
      NAMELIST /GENLOD/IFMM,IABB,VLGG,ZLL
      NAMELIST /ATTACH/NASAT,IABAT,NPLA,VGA,ZLDA,BDSK
      CHARACTER DATNAM*25,OUTNAM*25
      J(I,J,NTOT)=(J-1)*NTOT-(J*J-J)/2+I                                ESP01660
        AMP(GAM)=CABS(GAM)                                              ESP01670
C       PHS(GAM)=180.0*ATAN2(AIMAG(GAM),REAL(GAM))/3.1415926            ESP01680
C       OPEN(UNIT=6,NAME='OUTFL.DAT',TYPE='UNKNOWN')                    ESP01690
C                                                                       ESP01700
C       THE MAIN PROGRAM CONTAINS FOUR CALLS TO THE CLOCK FUNCTION      ESP01710
C       GETCP(I), WHERE I IS THE CLOCK READING IN HUNDREDTHS OF A       ESP01720
C       SECOND.  THESE FOUR LINES HAVE BEEN "COMMENTED" OUT.  IN ORDER  ESP01730
C       FOR THE CODE TO OUTPUT CPU TIMES, THE USER MUST REPLACE THESE   ESP01740
C       CALLS TO GETCP BY A COMPARABLE CLOCK FUNCTION ON HIS SYSTEM.    ESP01750
C                                                                       ESP01760
C  CALL GETCP2 PERFORMS THE CPU TIME FUNCTION ON THE SUN 3 SYSTEM
         CALL GETCP2(ICPU)                                              ESP01770
      PI=3.14159265                                                     ESP01780
        I9999=0                                                         ESP01790
        XJ=(0.0,1.0)                                                   ESP01800
        IANT=0                                                          ESP01810
C       INM= MAX. NUMBER WIRE SEGMENTS                                  ESP01820
C       ICJ= MAX. NUMBER WIRE MODES                                     ESP01830
C       IPLM= MAX. NUMBER PLATE MODES                                   ESP01840
C       ICC= MAX. SIZE OF 2-D ARRAY ZTF                                 ESP01850
        INM=IDWR                                                        ESP01860
        ICJ=IDWR                                                        ESP01870
        IPLM=ITOT                                                       ESP01880
        ICC=IDZTF                                                       ESP01890
C                                                                       ESP01900
C     NGO = 0 IMPLIES SET UP GEOMETRY BUT DO NOT RUN.                   ESP01910
C     NGO = 1 IMPLIES RUN.                                              ESP01920
C                                                                       ESP01930
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C     NPRINT = 0 IMPLIES PRINT INPUT DATA ONLY                          ESP01940
C     NPRINT = 1 IMPLIES PRINT WIRE AND PLATE GEOMETRY.                 ESP01950
C     NPRINT = 2 IMPLIES PRINT INPUT DATA AND WIRE/PLATE GEOMETRY.      ESP01960
C     NPRINT = 3 IMPLIES PRINT NEITHER.                                 ESP01970
C                                                                       ESP01980
      WRITE(6,2969)
2969  FORMAT(1X,'ENTER INPUT DATA FILE NAME (typically esp4nam.datax)')
      READ(5,*)DATNAM
      OPEN(11,FILE=DATNAM,FORM='FORMATTED')
      WRITE(6,3969)
3969  FORMAT(1X,'ENTER OUTPUT DATA FILE NAME (typ. esp4namfort.8)')
      READ(5,*)OUTNAM
      OPEN(8,FILE=OUTNAM,FORM='FORMATTED')
C     READ(11,*)NGO,NPRINT,NRUNS,NWGS,IWR,IWRZT,INT,INTP,INTD,INWR,IRGM,ESP01990
C    1IFIL,RF,INDZI                                                     ESP02000
      READ(11,RNCTRL)
C                                                                       ESP02010
C       READ IN PARAMETERS OF FREQUENCY SWEEP COMPUTATION               ESP02020
C                                                                       ESP02030
        I2468=0                                                         ESP02040
        IF(INDZI.NE.0)THEN                                              ESP02050
        IF(IDMZI.EQ.0)THEN                                              ESP02060
        WRITE(6,3215)                                                   ESP02070
 3215   FORMAT(3X,'DIMENSION INDICATOR IDMZI MUST BE SET TO 1 IF INDZI'/ESP02080
     2  3X,'IN READ 1 IS SET TO 1 OR 2')                                ESP02090
        STOP                                                            ESP02100
        ENDIF                                                           ESP02110
C       READ(11,*)FMC1,FMC2,DFZI,DFF,IRS12,THRD,PHRD,THINC,PHINC        ESP02120
      READ(11,FSWEEP)
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      DFTOT=(FMC2-FMC1)                                                 ESP02130
      NFZI=0.99+DFTOT/DFZI                                              ESP02140
      IF(NFZI.LT.2)NFZI=2                                               ESP02150
      DFZI=DFTOT/NFZI                                                   ESP02160
      NFZI=NFZI+1                                                       ESP02170
      NFF=0.99+DFTOT/DFF                                                ESP02180
      IF(NFF.LT.1)NFF=1                                                 ESP02190
      DFF=DFTOT/NFF                                                     ESP02200
      NFF=NFF+1                                                         ESP02210
      IF(NGO.NE.0)WRITE(10,3210)RF,THRD,PHRD,THINC,PHINC,IRS12,         ESP02220
     2  NFF,NFZI,INDZI                                                  ESP02230
 3210 FORMAT(1X,E11.5,4(1X,F6.1),1X,6I4)                                ESP02240
      II2LST=2                                                          ESP02250
      FNDFE=1.0                                                         ESP02260
      FNDFA=1.0                                                         ESP02270
      FNDSE=1.0                                                         ESP02280
      FNDSA=1.0                                                         ESP02290
      ENDIF                                                             ESP02300
      IF(INWR.EQ.0)THEN                                                 ESP02310
      NM=0                                                              ESP02320
      NP=0                                                              ESP02330
      NAT=0                                                             ESP02340
      NWR=0                                                             ESP02350
      NFPT=0                                                            ESP02360
      NFS1=0                                                            ESP02370
      NFS2=0                                                            ESP02380
      ENDIF                                                             ESP02390
      IF(INT.GT.0)INT=2*((INT+1)/2)                                     ESP02400
      INTP=2*((INTP+1)/2)                                               ESP02410
      INTD=2*((INTD+1)/2)                                               ESP02420
  270 FORMAT(2I1,2I3)                                                   ESP02430
C                                                                       ESP02440
C     READ IN PARAMETERS OF ELEVATION AND AZIMUTH PATTERNS              ESP02450
C     SET ALL TO 0 IF INDZI > 0                                         ESP02460
C                                                                       ESP02470
      IF(INDZI.EQ.0)THEN                                                ESP02480
C     READ(11,*)IFE,IPFE,FNDFE,PHFE                                     ESP02490
C     READ(11,*)IFA,IPFA,FNDFA,THFA                                     ESP02500
C     READ(11,*)ISE,IPSE,FNDSE,PHSE,THIN,PHIN                           ESP02510
C     READ(11,*)ISA,IPSA,FNDSA,THSA                                     ESP02520
CC***DEFAULT NAMELIST PATTRN VALUES FOR AZRANG,ELRANG,AZMIN,ELMIN,...
      AZRANG=360.
      ELRANG=360.
      AZMIN=0.
      ELMIN=0.
      IBISC=0
      BETA=0.
      NPTBIS=1
      BANGRG=0.
      READ(11,PATTRN)
      IF(IBISC.EQ.0)NPTBIS=1
      IF(IBISC.EQ.1)ELRANG=0.
      ELSE                                                              ESP02530
      IFE=0                                                             ESP02540
      IPFE=0                                                            ESP02550
      FNDFE=1.0                                                         ESP02560
      PHFE=0.0                                                          ESP02570
      IFA=0                                                             ESP02580
      IPFA=0                                                            ESP02590
      FNDFA=1.0                                                         ESP02600
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      THFA=0.0                                                          ESP02610
      ISE=0                                                             ESP02620
      IPSE=0                                                            ESP02630
      FNDSE=1.0                                                         ESP02640
      PHSE=0.0                                                          ESP02650
      THIN=0.0                                                          ESP02660
      PHIN=0.0                                                          ESP02670
      ISA=0                                                             ESP02680
      IPSA=0                                                            ESP02690
      FNDSA=1.0                                                         ESP02700
      THSA=0.0                                                          ESP02710
      ENDIF                                                             ESP02720
  312 FORMAT(3I2,F10.5)                                                 ESP02730
      IMAGE=0                                                           ESP02740
      IF(INDZI.EQ.0)THEN                                                ESP02750
      IF(ISE.LT.0.OR.ISA.LT.0)IMAGE=1                                   ESP02760
      ELSE                                                              ESP02770
      IF(IRS12.LT.0)IMAGE=1                                             ESP02780
      ENDIF                                                             ESP02790
      ISE=IABS(ISE)                                                     ESP02800
      ISA=IABS(ISA)                                                     ESP02810
      IFF=0                                                             ESP02820
      ISCAT=0                                                           ESP02830
      IF(INDZI.EQ.0)THEN                                                ESP02840
      IF(IFE+IFA+ISE+ISA.GE.1)IFF=1                                     ESP02850
      IF(ISE.EQ.1.OR.ISA.EQ.1)ISCAT=1                                   ESP02860
      IF(ISE.EQ.2.OR.ISA.EQ.2)ISCAT=2                                   ESP02870
      IF(ISE.EQ.3.OR.ISA.EQ.3)ISCAT=3                                   ESP02880
      ELSE                                                              ESP02890
      IFF=1                                                             ESP02900
      IF(IABS(IRS12).EQ.2)THEN                                          ESP02910
      ISCAT=2                                                           ESP02920
      IF(ABS(THINC-THRD)+ABS(PHINC-PHRD).LT.0.001)ISCAT=1               ESP02930
      ISE=1                                                             ESP02940
      ISA=0                                                             ESP02950
      ENDIF                                                             ESP02960
      IF(IABS(IRS12).EQ.1)THEN                                          ESP02970
      ISCAT=0                                                           ESP02980
      IFE=1                                                             ESP02990
      IFA=0                                                             ESP03000
      ENDIF                                                             ESP03010
      ENDIF                                                             ESP03020
C     NPLOTS = THE NUMBER OF PATTERN PLOTS                              ESP03030
C     IRS12 = 1 OR 2 FOR RADIATION OR SCATTERING PATTERNS               ESP03040
      NPLOTS=0                                                          ESP03050
      IF(ISCAT.EQ.0)THEN                                                ESP03060
      IF(IFE.NE.0.AND.IPFE.EQ.1)NPLOTS=NPLOTS+1                         ESP03070
      IF(IFA.NE.0.AND.IPFA.EQ.1)NPLOTS=NPLOTS+1                         ESP03080
      ELSE                                                              ESP03090
      IF(ISE.NE.0.AND.IPSE.EQ.1)NPLOTS=NPLOTS+1                         ESP03100
      IF(ISA.NE.0.AND.IPSA.EQ.1)NPLOTS=NPLOTS+1                         ESP03110
      ENDIF                                                             ESP03120
      IF(INDZI.EQ.0)THEN                                                ESP03130
      IRS12=1                                                           ESP03140
      IF(ISCAT.NE.0)IRS12=2                                             ESP03150
      ENDIF                                                             ESP03160
    DO 700 NRUN=1,NRUNS                                                 ESP03170
C                                                                       ESP03180
C     READ FREQUENCY, WIRE CONDUCTIVITY, AND WIRE RADIUS                ESP03190
C                                                                       ESP03200
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C       READ(11,*)FMC,CMM,A                                          ESP03210
      READ(11,FWIRET)
        IF(INDZI.NE.0)FMC=FMC2                                       ESP03220
        IF(NPLOTS.GT.0.AND.INDZI.EQ.0.AND.NGO.NE.0)                  ESP03230
     2  WRITE(8,337)NPLOTS,IRS12,FMC,RF                              ESP03240
  337   FORMAT(1X,2(I3,1X),2(F11.4,2X))                              ESP03250
        WV=300.0/FMC                                                 ESP03260
        TOUCH=0.001*WV                                               ESP03270
        IOK=1                                                        ESP03280
C                                                                    ESP03290
C       READ IN THE NUMBER OF PLATES                                 ESP03300
C                                                                    ESP03310
C       READ(11,*)NPLTS                                              ESP03320
        SEGMX=-1.0                                                   ESP03330
        IF(NPLTS.GT.IPL)THEN                                         ESP03340
        WRITE(6,330)NPLTS                                            ESP03350
  330   FORMAT(' ****** INCREASE PARAMETER IPL TO ',I4)              ESP03360
        STOP                                                         ESP03370
        ENDIF                                                        ESP03380
        NOVT=0                                                       ESP03390
        NPLTM=0                                                      ESP03400
        IF(NPLTS.EQ.0)GOTO462                                        ESP03410
        IOKT=1                                                       ESP03420
C                                                                    ESP03430
C       IF NPLTS < 0, GENERATE PLATE GEOMETRY IN CGEOM               ESP03440
C                                                                    ESP03450
        IF(NPLTS.LT.0)THEN                                           ESP03460
C                                                                    ESP03470
C       PLATE GEOMETRY GENERATED IN SUBROUTINE CALL BELOW            ESP03480
C       SUBROUTINE PGEOM IS CONTAINED IN ESP4PGM FORTRAN.            ESP03490
C                                                                    ESP03500
      CALL PGEOM(IPL,ICN,NPLTS,NCNRS,SEGM,IREC,IPN,IGS,ZSHT,PCN)     ESP03510
         IF(NPLTS.GT.IPL)THEN                                        ESP03520
         WRITE(6,330)NPLTS                                           ESP03530
         STOP                                                        ESP03540
         ENDIF                                                       ESP03550
         ELSE                                                        ESP03560
C                                                                    ESP03570
C       READ IN THE PLATE GEOMETRY                                   ESP03580
C                                                                    ESP03590
        DO 464 NPL=1,NPLTS                                           ESP03600
C       READ(11,*)NCNRS(NPL),SEGM(NPL),IREC(NPL),IPN(NPL),IGS(NPL),  ESP03610
C    2  ZSHT(NPL)                                                    ESP03620
      READ(11,PLATEG)
      WRITE(6,PLATEG)
        IF(SEGM(NPL).GT.SEGMX)SEGMX=SEGM(NPL)                        ESP03630
        IF(NCNRS(NPL).EQ.4)IGS(NPL)=0                                ESP03640
        IF(NCNRS(NPL).GT.ICN)THEN                                    ESP03650
        WRITE(6,331)NCNRS(NPL)                                       ESP03660
  331   FORMAT(' ****** INCREASE PARAMETER ICN TO AT LEAST ',I4)     ESP03670
        STOP                                                         ESP03680
        ENDIF                                                        ESP03690
        DO 466 NCNR=1,NCNRS(NPL)                                     ESP03700
C       READ(11,*)PCN(1,NCNR,NPL),PCN(2,NCNR,NPL),PCN(3,NCNR,NPL)   ESP03710
C***FILL-IN PCN ARRAY FROM NAMELIST DATA
      PCN(1,NCNR,NPL)=XP(NCNR)
      PCN(2,NCNR,NPL)=YP(NCNR)
      PCN(3,NCNR,NPL)=ZP(NCNR)
  466   CONTINUE                                                     ESP03720
  464   CONTINUE                                                     ESP03730
```

```
        END IF                                                          ESP03740
      DO 466 NPL=1,NPLTS                                                ESP03750
      CALL PLPLCK(PCN,IPL,ICN,NCNRS(NPL),TOUCH,NPL,IOK)                 ESP03760
      IF (IOK.EQ.0) IOKT=0                                              ESP03770
 465  CONTINUE                                                          ESP03780
        IF(IOKT.EQ.0) GOTO 9374                                         ESP03790
        DO 467 NPL=1,NPLTS                                              ESP03800
        NCNS=NCNRS(NPL)                                                 ESP03810
        SEG=SEGM(NPL)                                                   ESP03820
        IRE=IREC(NPL)                                                   ESP03830
        IP=IPN(NPL)                                                     ESP03840
        IG=IGS(NPL)                                                     ESP03850
        DO 468 NC=1,NCNS                                                ESP03860
        DO 468 I=1,3                                                    ESP03870
  468   PC(I,NC)=PCN(I,NC,NPL)                                          ESP03880
C                                                                       ESP03890
C       SEGMENT PLATES INTO MODES                                       ESP03900
C                                                                       ESP03910
        CALL PLATE3(PC,NCNS,ICN,NPL,NDNPLT,PA,PB,IPLM,SEG,              ESP03920
     1  IQUAD,WV,IRE,IP,MPL1,MPL2,IOK,NM12,NM23,IG)                     ESP03930
        IF(NPL.EQ.NPLTS)NPLTM=NDNPLT(NPLTS)                             ESP03940
        NPL11(NPL)=MPL1                                                 ESP03950
        NPL22(NPL)=MPL2                                                 ESP03960
C*****************                                                      ESP03970
        NM12N(NPL)=NM12                                                 ESP03980
        NM23N(NPL)=NM23                                                 ESP03990
C************************                                               ESP04000
  467   CONTINUE                                                        ESP04010
C                                                                       ESP04020
C       CONNECT TOUCHING PLATES WITH OVERLAP MODES                      ESP04030
C                                                                       ESP04040
        CALL POPLOV(NPLTS,PCN,NCNRS,TOUCH,                              ESP04050
     &  SEGM,PA,PB,NOVT,NPLTM,IPL,IPLM,ICN,IOVT,DOVL,ITK,NOPL,          ESP04060
     &  IQUAD,WV,NDNPLT,OVEP)                                           ESP04070
  462   CONTINUE                                                        ESP04080
        NPLTM=NPLTM+NOVT                                                ESP04090
        DO 600 NWG=1,NWGS                                               ESP04100
        I12=1                                                           ESP04110
         CALL GETCP2(JCPU)                                              ESP04120
        IWRZM=0                                                         ESP04130
        IRDZM=0                                                         ESP04140
C                                                                       ESP04150
C       READ IN Z MATRIX READ/WRITE FROM DISK INDICATORS                ESP04160
C                                                                       ESP04170
C       READ(11,*)IWRZM,IRDZM                                           ESP04180
      READ(11,SAVEZ)
C       IF(INDZI.GT.0)THEN                                              ESP04190
C       IWRZM=0                                                         ESP04200
C       IRDZM=0                                                         ESP04210
C       ENDIF                                                           ESP04220
        WV=300.0/FMC                                                    ESP04230
        INM2=2*INM                                                      ESP04240
        DO 2774 I=1,INM2                                                ESP04250
        ZLD(I)=CMPLX(0.0,0.0)                                           ESP04260
        VG(I)=CMPLX(0.0,0.0)                                            ESP04270
        IF(I.GT.IAT)GOTO2774                                            ESP04280
        VGA(I)=CMPLX(0.0,0.0)                                           ESP04290
        ZLDA(I)=CMPLX(0.0,0.0)                                          ESP04300
 2774   CONTINUE                                                        ESP04310
      IF(INWR.EQ.0) NWR=0                                               ESP04320
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      IF(INWR.EQ.0) NAT=0                                              ESP04330
        IF(INWR.EQ.0)GOTO2773                                          ESP04340
        IF(IRGM.EQ.0)GOTO2800                                          ESP04350
C                                                                      ESP04360
C     SET UP POINTS AND SEGMENTS.                                      ESP04370
C                                                                      ESP04380
C       READ(11,*)NM,NP,NAT,NFPT,NFS1,NFS2                             ESP04390
      READ(11,WIREAG)
        IF(NAT.GT.IAT)THEN                                             ESP04400
        WRITE(6,332)NAT                                                ESP04410
  332   FORMAT(' ****** INCREASE PARAMETER IAT TO AT LEAST ',I4)        ESP04420
        STOP                                                           ESP04430
        ENDIF                                                          ESP04440
C                                                                      ESP04450
C       READ IN COOR. OF NP POINTS                                     ESP04460
C                                                                      ESP04470
        DO 2810 I=1,NP                                                 ESP04480
C       READ(11,*)X(I),Y(I),Z(I)                                       ESP04490
 2810   CONTINUE                                                       ESP04500
C                                                                      ESP04510
C       READ IN ENDPOINTS OF NM SEGMENTS                               ESP04520
C                                                                      ESP04530
        DO 2820 I=1,NM                                                 ESP04540
C       READ(11,*)IA(I),IB(I)                                          ESP04550
 2820   CONTINUE                                                       ESP04560
C                                                                      ESP04570
C       READ IN WIRE GENERATORS AND LOADS                              ESP04580
C                                                                      ESP04590
      READ(11,GENLOD)
        DO 2830 I=1,NFPT                                               ESP04600
C       IF(NFPT.GE.1)READ(11,*)IFM,IAB,VLG,ZL                          ESP04610
C       II=IFM+IAB*NM                                                  ESP04620
      II=IFMM(I)+IABB(I)*NM
        VG(II)=VLGG(I)                                                 ESP04630
        ZLD(II)=ZLL(I)                                                 ESP04640
 2830   CONTINUE                                                       ESP04650
C                                                                      ESP04660
C       READ IN ATTACHMENT POINT GEOMETRY                              ESP04670
C                                                                      ESP04680
        IF(NAT.EQ.0)GOTO2850                                           ESP04690
      READ(11,ATTACH)
        DO 2840 I=1,NAT                                                ESP04700
C       READ(11,*)NAS,IAB,NPLA(I),VGA(I),ZLDA(I),BDSK(I)               ESP04710
C       NSA(I)=NAS+IAB*NM                                              ESP04720
      NSA(I)=NASAT(I)+IABAT(I)*NM
 2840   CONTINUE                                                       ESP04730
        GOTO2850                                                       ESP04740
C                                                                      ESP04750
C       IF IRGM = 0, GENERATE WIRE GEOMETRY IN SUBROUTINE WGEOM        ESP04760
C                                                                      ESP04770
 2800   CALL WGEOM(IA,IB,X,Y,Z,NM,NP,NAT,NSA,NPLA,VGA,BDSK,           ESP04780
     2  ZLDA,NWG,VG,ZLD,WV,NFS1,NFS2)                                  ESP04790
 2850   CONTINUE                                                       ESP04800
        IF(IFIL.EQ.1.AND.NAT.GT.0)THEN                                 ESP04810
        WRITE(6,2852)                                                  ESP04820
 2852   FORMAT(/3X,'ERROR: FILAMENT TESTING CAN NOT BE USED IF ',      ESP04830
     2  'GEOMETRY CONTAINS A WIRE/PLATE ATTACHMENT'/3X,                ESP04840
     3  'SET IFIL = 0 IN READ 1')                                      ESP04850
        STOP                                                           ESP04860
        ENDIF                                                          ESP04870
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C                                                                       ESP04880
C       PLACE MODES ON THE WIRE                                         ESP04890
C                                                                       ESP04900
        CALL SORT(IA,IB,I1,I2,I3,JA,JB,MD,ND,NM,NP,NWR,MAX,MIN,ICJ,INM) ESP04910
        NDWR=MAXO(NM,NP,NWR)                                            ESP04920
        IF(NDWR.GT.IDWR)THEN                                            ESP04930
        WRITE(6,335)NDWR                                                ESP04940
  335   FORMAT(' ****** INCREASE PARAMETER IDWR TO AT LEAST ',I4)       ESP04950
        STOP                                                            ESP04960
        ENDIF                                                           ESP04970
 2773   CONTINUE                                                        ESP04980
C                                                                       ESP04990
C       DETERMINE ON WHICH PLATES SURFACE PATCH MODES LIE                ESP05000
C                                                                       ESP05010
        DO 2048 I=1,NPLTM                                               ESP05020
        CALL WCHPLT(I,NPLTS,NOPL,NDNPLT,IOVT,ITK,ITOT,MPLA,MPLB)        ESP05030
 2048   CONTINUE                                                        ESP05040
        NTOT=NWR+NPLTM+NAT                                              ESP05050
        IF(NTOT.GT.ITOT)THEN                                            ESP05060
        WRITE(6,334)NTOT                                                ESP05070
 334    FORMAT(' ****** INCREASE PARAMETER ITOT TO AT LEAST ',I5)       ESP05080
        STOP                                                            ESP05090
        ENDIF                                                           ESP05100
        N1=NPLTM-NOVT+1                                                 ESP05110
        N2=NPLTM                                                        ESP05120
        IF(NOVT.GT.0)THEN                                               ESP05130
        DO 665 I=N1,N2                                                  ESP05140
665     IQUAD(I)=0                                                      ESP05150
        ENDIF                                                           ESP05160
        NZT=(NTOT**2+NTOT)/2                                            ESP05170
        FHZ=FMC*1.0E6                                                   ESP05180
      ETA=(376.7,0.)                                                    ESP05190
      GAM=CMPLX(0.,2.*PI/WV)                                            ESP05200
      XK=2.*PI/WV                                                       ESP05210
      Q=.001*WV                                                         ESP05220
        IF(NWR.EQ.0)A=Q                                                 ESP05230
C                                                                       ESP05240
C     SET UP SLEEVES, NO SLEEVES (1, 0) ON THE SEGMENTS.                ESP05250
C                                                                       ESP05260
      DO 125 I=1,INM                                                    ESP05270
      ISC(I)=0                                                          ESP05280
  125 CONTINUE                                                          ESP05290
        IF(NGO.EQ.0)THEN                                                FSP05300
C                                                                       ESP05310
C       WRITE OUT WIRE/PLATE/OVERLAP GEOMETRY FOR GKS PLOTTING          ESP05320
C                                                                       ESP05330
        WRITE(9,*)NPLTS,NPLTM,NM,NP,NWR,NAT,WV,NOPL,NOVT                ESP05340
        DO 158 I=1,NP                                                   ESP05350
        WRITE(9,*)X(I),Y(I),Z(I)                                        ESP05360
  158   CONTINUE                                                        ESP05370
        DO 159 I=1,NM                                                   ESP05380
        WRITE(9,*)IA(I),IB(I)                                           ESP05390
  159   CONTINUE                                                        ESP05400
        DO 151 NPL=1,NPLTS                                              ESP05410
  151   WRITE(9,*)NCNRS(NPL),NPL11(NPL),NPL22(NPL),NDNPLT(NPL),IPN(NPL) ESP05420
        DO 152 I=1,NPLTM                                                ESP05430
        DO 153 J=1,4                                                    ESP05440
        WRITE(9,*)PA(I,J,1),PA(I,J,2),PA(I,J,3),PB(I,J,1),PB(I,J,2),    ESP05450
     2  PB(I,J,3)                                                       ESP05460
  153   CONTINUE                                                        ESP05470
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  152   CONTINUE                                                        ESP05480
        DO 156 NPL=1,NPLTS                                              ESP05490
        NCNR=NCNRS(NPL)                                                 ESP05500
        DO 157 NC=1,NCNR                                                ESP05510
        WRITE(9,*)PCN(1,NC,NPL),PCN(2,NC,NPL),PCN(3,NC,NPL)             ESP05520
  157   CONTINUE                                                        ESP05530
  156   CONTINUE                                                        ESP05540
        DO 166 I=1,NOPL                                                 ESP05550
        WRITE(9,*)IOVT(I,1),IOVT(I,2),IOVT(I,3),IOVT(I,4),ITK(I)        ESP05560
  166   CONTINUE                                                        ESP05570
        ENDIF                                                           ESP05580
C       END GKS PLOTTING OUTPUT                                         ESP05590
      IF(NPRINT.NE.0.AND.NPRINT.NE.2)GOTO610                            ESP05600
C                                                                       ESP05610
C     WRITE OUT INPUT DATA.                                             ESP05620
C                                                                       ESP05630
      WRITE(6,621)FMC,WV,A,INTP,INTD,INT,IFIL                           ESP05640
  621 FORMAT(/3X,'OHIO STATE UNIVERSITY ELECTROMAGNETIC SURFACE '       ESP05650
     2  'PATCH (ESP) CODE: VERSION IV'                                  ESP05660
     2  //10X,'INPUT DATA'//3X,'FREQ.(MHZ)=',F10.3,3X,'WAVE(M)=',      ESP05670
     2F10.3,3X,'WIRE RAD(M)= ',F9.6,/,                                  ESP05680
     33X,'INTP=',I4,3X,'INTD=',I4,3X,'INT = ',I4,3X,'IFIL=',I2)         ESP05690
      WRITE(6,623) CMM                                                  ESP05700
623   FORMAT(3X,'WIRE CONDUCTIVITY =',F6.2,' MEGAMHOS/M')               ESP05710
        WRITE(6,3006)IDWR,ITW2,ICN,IPL,IAT,ITOT,IDZT,IDZTF,IDMI,        ESP05720
     2  IDZTI,IDZTFI,IDMZI                                              ESP05730
 3006   FORMAT(/3X,'SUMMARY OF ARRAY DIMENSIONS'/3X,'IDWR = ',I4/       ESP05740
     2  3X,'ITW2 = ',I4/3X,'ICN = ',I4/3X,'IPL = ',I4/                  ESP05750
     3  3X,'IAT = ',I4/3X,'ITOT = ',I4/3X,'IDZT = ',I7/                 ESP05760
     4  3X,'IDZTF = ',I4/3X,'IDMI = ',I4/3X,'IDZTI = ',I7/              ESP05770
     5  3X,'IDZTFI = ',I4/3X,'IDMZI = ',I2)                             ESP05780
        WRITE(6,3006)IWRZM,IRDZM                                        ESP05790
 3006   FORMAT(/3X,'MATRIX WRITE AND READ Z FROM DISK INDICATORS:'/     ESP05800
     2  3X,'IWRZM = ',I2,5X,'IRDZM = ',I2)                              ESP05810
C                                                                       ESP05820
C     WRITE OUT PLATE GEOMETRY.                                         ESP05830
C                                                                       ESP05840
  520 FORMAT(2X,'X,Y,Z COOR. (METERS) OF CORNER ',I2,' =',3F12.5)       ESP05850
  525 FORMAT(//3X,'COOR. (METERS) OF ',I3,' MODES ON PLATE ',I3,/)      ESP05860
  526 FORMAT(//3X,'THERE ARE ',I3,' MODES ON PLATE ',I3,/)              ESP05870
  530 FORMAT(3X,'I  XA1   YA1   ZA1   XA2   YA2   ZA2  ',               ESP05880
     2' XA3   YA3   ZA3   XB1   YB1   ZB1   XB2  ',                   ESP05890
     3' YB2   ZB2   XB3   YB3   ZB3  '/)                               ESP05900
  550 FORMAT(1X,I3,1X,18(F4.2))                                         ESP05910
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      WRITE(6,471)NPLTS                                                 ESP05920
  471 FORMAT(/3X,'GEOMETRY FOR THE ',I3,' PLATES')                      ESP05930
      IF(NPLTS.LE.0)GOTO610                                             ESP05940
      DO 472 NPL=1,NPLTS                                                ESP05950
      IF(IREC(NPL).EQ.1)WRITE(6,473)NPL,NCNRS(NPL),SEGM(NPL),           ESP05960
     1 IPN(NPL),IGS(NPL),ZSHT(NPL)                                      ESP05970
  473 FORMAT(//25X,'PLATE NUMBER ',I3,'  (RECTANGULAR)'                 ESP05980
     1 /3X,'NUMBER OF CORNERS = ',I3/3X,'MAXIMUM SEGMENT SIZE',         ESP05990
     2 2X,'(WAVELENGTH) = ',F10.5/3X,'POLARIZATION INDICATOR = ',I3/3X,ESP06000
     3 'GENERATING SIDE INDICATOR = ',I3/                               ESP06010
     4 3X,'SHEET IMPEDANCE (OHMS/SQ.) = ',E11.4,'+J ',E11.4)            ESP06020
      IF(IREC(NPL).EQ.0)WRITE(6,444)NPL,NCNRS(NPL),SEGM(NPL),           ESP06030
     1 IPN(NPL),IGS(NPL),ZSHT(NPL)                                      ESP06040
  444 FORMAT(///25X,'PLATE NUMBER ',I3,'  (POLYGONAL)'                  ESP06050
     1 /3X,'NUMBER OF CORNERS = ',I3/3X,'MAXIMUM SEGMENT SIZE',         ESP06060
     2 2X,'(WAVELENGTH) = ',F10.5/3X,'POLARIZATION INDICATOR = ',I3/3X,ESP06070
     3 'GENERATING SIDE INDICATOR = ',I3/                               ESP06080
     4 3X,'SHEET IMPEDANCE (OHMS/SQ.) = ',E11.4,'+J ',E11.4)            ESP06090
      DO 474 NCNR=1,NCNRS(NPL)                                          ESP06100
  474 WRITE(6,520)NCNR,PCN(1,NCNR,NPL),PCN(2,NCNR,NPL),PCN(3,NCNR,NPL)ESP06110
      N2=NDNPLT(NPL)                                                    ESP06120
      N1=NPL-1                                                          ESP06130
      NA=1                                                              ESP06140
      IF(NPL.GT.1) NA=NDNPLT(N1)+1                                      ESP06150
      IF(NPL.GT.1) NN=N2-NA+1                                           ESP06160
      IF(NPL.EQ.1) NN=N2                                                ESP06170
      IF(IWR.GE.1)THEN                                                  ESP06180
      WRITE (6,525)NN,NPL                                               ESP06190
      ELSE                                                              ESP06200
      WRITE (6,526)NN,NPL                                               ESP06210
      ENDIF                                                             ESP06220
      IF(IWR.LE.0)GO TO 472                                             ESP06230
      WRITE(6,531)                                                      ESP06240
  531 FORMAT(1X,'MONOPOLE   MODE     X1       Y1       Z1       X2',   ESP06250
     1 '       Y2       Z2       X3       Y3       Z3       X4',       ESP06260
     2 '       Y4       Z4 '/)                                         ESP06270
      DO 541 I=NA,N2                                                    ESP06280
      WRITE(6,551) I,((PA(I,J,K),K=1,3),J=1,4)                          ESP06290
  551 FORMAT (4X,' A  ',3X,I3,2X,12(F9.5))                              ESP06300
      WRITE(6,552) I,((PB(I,J,K),K=1,3),J=1,4)                          ESP06310
  552 FORMAT (4X,' B  ',3X,I3,2X,12(F9.5)/)                             ESP06320
  541 CONTINUE                                                          ESP06330
  472 CONTINUE                                                          ESP06340
C                                                                       ESP06350
C     WRITE OUT OVERLAP MODES                                           ESP06360
C                                                                       ESP06370
    IF (NOVT .EQ. 0) GOTO 610                                           ESP06380
      IMX=0                                                             ESP06390
      DO 2039 I=1,NOPL                                                  ESP06400
      IF(IOVT(I,2) .EQ. 0)                                              ESP06410
     &  WRITE(6,2031)ITK(I),IOVT(I,1),IOVT(I,3),IOVT(I,4)               ESP06420
      IF(IOVT(I,4) .EQ. 0)                                              ESP06430
     &  WRITE(6,2031)ITK(I),IOVT(I,3),IOVT(I,1),IOVT(I,2)               ESP06440
      IF((IOVT(I,2) .EQ. 0 .OR. IOVT(I,4) .EQ. 0) .AND.                 ESP06450
     &  DOVL(I) .LT. 0.1*WV) WRITE(6,2032)DOVL(I)                       ESP06460
      IF(IOVT(I,2) .NE. 0 .AND. IOVT(I,4) .NE. 0)THEN                   ESP06470
      IF(IWR.LE.0)THEN                                                  ESP06480
       WRITE(6,2033)ITK(I),IOVT(I,1),IOVT(I,2),IOVT(I,3),IOVT(I,4)      ESP06490
      ELSEIF(IWR.GE.1)THEN                                              ESP06500
       WRITE(6,2030)ITK(I),IOVT(I,1),IOVT(I,2),IOVT(I,3),IOVT(I,4)      ESP06510
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      ENDIF                                                          ESP06520
      ENDIF                                                          ESP06530
      IF(IWR .LE. 0 .OR. ITK(I) .EQ. 0) GOTO 2039                    ESP06540
      IMN=IMX+1                                                      ESP06550
      IMX=IMX+ITK(I)                                                 ESP06560
      DO 2040 ICT=IMN,IMX                                            ESP06570
      II=NPLTM-NOVT+ICT                                              ESP06580
2041  IF(ICT.EQ.IMN)WRITE(6,631)                                     ESP06590
      WRITE(6,551)II,((PA(II,J,K),K=1,3),J=1,4)                      ESP06600
      WRITE(6,552)II,((PB(II,J,K),K=1,3),J=1,4)                      ESP06610
2040  CONTINUE                                                       ESP06620
2039  CONTINUE                                                       ESP06630
2030  FORMAT(//3X,'COOR. (METERS) OF ',I3,' OVERLAP MODES',          ESP06640
     & ' BETWEEN'/3X,'PLATE',I3,', SIDE',I2,' AND PLATE',I3,         ESP06650
     & ', SIDE',I2/)                                                 ESP06660
2033  FORMAT(//3X,'THERE ARE ',I3,' OVERLAP MODES',                  ESP06670
     & ' BETWEEN'/3X,'PLATE',I3,', SIDE',I2,' AND PLATE',I3,         ESP06680
     & ', SIDE',I2/)                                                 ESP06690
2031  FORMAT(//3X,'COOR. (METERS) OF ',I3,' OVERLAP MODES',          ESP06700
     &  ' BETWEEN FACE OF PLATE',I3,' AND PLATE ',I3,' SIDE ',I2/)   ESP06710
2032  FORMAT(3X,'***** WARNING:  LENGTH OF OVERLAP MODE = ',         ESP06720
     &  1PE10.2,' LESS THAN 0.1*WAVELENGTH')                         ESP06730
  610 CONTINUE                                                       ESP06740
C                                                                    ESP06750
C     WRITE OUT LIST OF PLATE SURFACE PATCH MODE LOCATIONS           ESP06760
C                                                                    ESP06770
      IF(IWR.GE.1)THEN                                               ESP06780
      WRITE(6,2045)                                                  ESP06790
 2045 FORMAT(//3X,'LIST OF PLATES ON WHICH SURFACE PATCH MODES LIE'   ESP06800
     2 /4X,'N',3X,'N-NWR',3X,'MON. A',3X,'MON. B'/)                  ESP06810
      DO2046IL=1,NPLTM                                               ESP06820
      I=IL+NWR                                                       ESP06830
      WRITE(6,2047)I,IL,MPLA(IL),MPLB(IL)                            ESP06840
 2047 FORMAT(1X,I4,3X,I4,5X,I3,7X,I3)                                ESP06850
 2046 CONTINUE                                                       ESP06860
      ENDIF                                                          ESP06870
      IF(NPRINT.NE.1.AND.NPRINT.NE.2)GOTO620                         ESP06880
      IF(NWR.EQ.0)GOTO726                                            ESP06890
C                                                                    ESP06900
C     WRITE OUT POINTS AND SEGMENTS.                                 ESP06910
C                                                                    ESP06920
      WRITE(6,130)NP                                                 ESP06930
  130 FORMAT(///5X,I3,' POINTS ON THE WIRE (METERS)',/5X,'I',9X,     ESP06940
     2'X (I)',9X,'Y (I)',9X,'Z (I)',/)                               ESP06950
      DO140I=1,NP                                                    ESP06960
      WRITE(6,150)I,X(I),Y(I),Z(I)                                   ESP06970
  150 FORMAT(3X,I3,3(2X,E11.4,2X))                                   ESP06980
  140 CONTINUE                                                       ESP06990
  160 FORMAT(///5X,I3,' SEGMENTS ON THE WIRE',/5X,'J',4X,'IA(J)',    ESP07000
     23X,'IB(J)',2X,'D(J) (METERS)'/)                                ESP07010
      WRITE(6,190)MAX,MIN,NWR                                        ESP07020
  190 FORMAT(///5X,'MODES ON THE WIRE STRUCTURE',//5X,'MAXIMUM NUMBER ESP07030
     2 OF MODES AT ONE POINT = ',I2/5X,'MINIMUM NUMBER OF MODES AT ONE ESP07040
     3OINT = ',I2/5X,'NUMBER OF WIRE MODES = ',I3/)                  ESP07050
        IF(IWR.LE.0)GOTO729                                          ESP07060
      WRITE(6,200)                                                   ESP07070
  200 FORMAT(/5X,'I',2X,'I1(I)',2X,'I2(I)',2X,'I3(I)',2X,'JA(I)',2X, ESP07080
     2'JB(I)',/)                                                     ESP07090
      DO210I=1,NWR                                                   ESP07100
      WRITE(6,220)I,I1(I),I2(I),I3(I),JA(I),JB(I)                    ESP07110
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  220 FORMAT(2X,6(I3,4X))                                                ESP07120
  210 CONTINUE                                                           ESP07130
  729   WRITE(6,160)NM                                                   ESP07140
  230 FORMAT(//5X,'SEGMENT LENGTHS(M)',/5X,'J',3X,'IA(J)',3X,'IB(J)',    ESP07150
     29X,'D (J)',/)                                                      ESP07160
      DO 70 J=1,NM                                                       ESP07170
      K=IA(J)                                                            ESP07180
      L=IB(J)                                                            ESP07190
      D(J)=SQRT((X(K)-X(L))**2+(Y(K)-Y(L))**2+(Z(K)-Z(L))**2)            ESP07200
        EGD=CEXP(GAM*D(J))                                               ESP07210
        SGD(J)=(EGD-1.0/EGD)/2.0                                         ESP07220
        CGD(J)=(EGD+1.0/EGD)/2.0                                         ESP07230
      WRITE(6,240)J,IA(J),IB(J),D (J)                                    ESP07240
  240 FORMAT(3X,I3,4X,I3,5X,I3,3X,E13.6)                                 ESP07250
  70  CONTINUE                                                           ESP07260
C                                                                        ESP07270
C     WRITE OUT ATTACHMENT POINT GEOMETRY.                               ESP07280
C                                                                        ESP07290
  726 IF(NAT.LE.0)GOTO620                                                ESP07300
      WRITE(6,560)NAT                                                    ESP07310
  560 FORMAT(/////3X,'GEOMETRY FOR THE ',I2,' ATTACHMENT POINTS'/)       ESP07320
      WRITE(6,570)                                                       ESP07330
  570 FORMAT(3X,'I  SEGMENT  END  PLATE    B (METERS)'/)                 ESP07340
      DO580NA=1,NAT                                                      ESP07350
      NND=0                                                              ESP07360
      IF(NSA(NA).GT.NM)NND=1                                             ESP07370
        MMD=NND+1                                                        ESP07380
      NAS=NSA(NA)-(MMD-1)*NM                                             ESP07390
      WRITE(6,590)NA,NAS,NND,NPLA(NA),BDSK(NA)                           ESP07400
  590 FORMAT(2X,I2,3X,I4,5X,I1,5X,I2,5X,F8.5)                            ESP07410
  580 CONTINUE                                                           ESP07420
  620 CONTINUE                                                           ESP07430
        WRITE(6,722)                                                     ESP07440
  722   FORMAT(//5X,'LISTING OF LOADS AND GENERATORS'/)                  ESP07450
        DO622J=1,NM                                                      ESP07460
        IF(CABS(VG(J)).GT.1.0E-6)WRITE(6,723)VG(J),J                     ESP07470
        IF(CABS(VG(J)).GT.1.0E-6)IANT=1                                  ESP07480
        IF(CABS(ZLD(J)).GT.1.0E-6)WRITE(6,624)ZLD(J),J                   ESP07490
        JJ=J+NM                                                          ESP07500
        IF(CABS(VG(JJ)).GT.1.0E-6)WRITE(6,625)VG(JJ),J                   ESP07510
        IF(CABS(VG(JJ)).GT.1.0E-6)IANT=1                                 ESP07520
        IF(CABS(ZLD(JJ)).GT.1.0E-6)WRITE(6,626)ZLD(JJ),J                 ESP07530
  723   FORMAT(3X,2E13.4,' VOLTS BY PT. A OF SEGMENT ',I3)               ESP07540
  624   FORMAT(3X,2E13.4,' OHMS BY PT. A OF SEGMENT ',I3)                ESP07550
  625   FORMAT(3X,2E13.4,' VOLTS BY PT. B OF SEGMENT ',I3)               ESP07560
  626   FORMAT(3X,2E13.4,' OHMS BY PT. B OF SEGMENT ',I3)                ESP07570
  622   CONTINUE                                                         ESP07580
        DO627J=1,NAT                                                     ESP07590
        IF(NAT.EQ.0)GOTO627                                              ESP07600
        IF(CABS(VGA(J)).GT.1.0E-6)WRITE(6,628)VGA(J),J                   ESP07610
        IF(CABS(VGA(J)).GT.1.0E-6)IANT=1                                 ESP07620
        IF(CABS(ZLDA(J)).GT.1.0E-6)WRITE(6,629)ZLDA(J),J                 ESP07630
  628   FORMAT(3X,2E13.4,' VOLTS AT ATTACHMENT ',I2)                     ESP07640
  629   FORMAT(3X,2E13.4,' OHMS AT ATTACHMENT ',I2)                      ESP07650
  627   CONTINUE                                                         ESP07660
        WRITE(6,633)NWR,NPLTH,NAT                                        ESP07670
  633   FORMAT(//5X,'NWR = NUMBER OF WIRE MODES = ',I4/5X,               ESP07680
     2  'NPLTH = NUMBER OF PLATE MODES = ',I4/5X,                        ESP07690
     3  'NAT = NUMBER OF ATTACHMENT MODES = ',I4//)                      ESP07700
        ICP=0                                                            ESP07710
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      IF(NFS1.GT.0.AND.NFS2.GT.0)ICP=1                                  ESP07720
      IF(ICP.EQ.0)GO TO 1226                                            ESP07730
      WRITE(6,141)                                                      ESP07740
  141 FORMAT(//3X,'DEFINITION OF PORTS FOR MUTUAL COUPLING DATA'/)      ESP07750
      DO127NF=1,2                                                       ESP07760
      NFM=0                                                             ESP07770
      SN=1.0                                                            ESP07780
      NFS=NFS1                                                          ESP07790
      IF(NF.EQ.2)NFS=NFS2                                               ESP07800
      DO128I=1,NWR                                                      ESP07810
      IF(NFS.GT.NM)GOTO129                                              ESP07820
      IF(I2(I).NE.IA(NFS))GOTO128                                       ESP07830
      NFM=I                                                             ESP07840
      IF(JA(I).EQ.NFS)SN=-1.0                                           ESP07850
      WRITE(6,142)NF,NFS                                                ESP07860
  142 FORMAT(3X,'PORT ',I2,' IS BY PT. A OF SEGMENT',I4)                ESP07870
      GOTO128                                                           ESP07880
  129 IF(I2(I).NE.IB(NFS-NM))GOTO128                                    ESP07890
      NFM=I                                                             ESP07900
      IF(JB(I).EQ.NFS-NM)SN=-1.0                                        ESP07910
      NFSNM=NFS-NM                                                      ESP07920
      WRITE(6,143)NF,NFSNM                                              ESP07930
  143 FORMAT(3X,'PORT ',I2,' IS BY PT. B OF SEGMENT',I4)                ESP07940
  128 CONTINUE                                                          ESP07950
      IF(NFM.GT.0.OR.NAT.EQ.0)GOTO131                                   ESP07960
      DO132I=1,NAT                                                      ESP07970
      IF(NFS.NE.NSA(I))GOTO132                                          ESP07980
      NFM=NWR+NPLTM+I                                                   ESP07990
      WRITE(6,144)NF,I                                                  ESP08000
  144 FORMAT(3X,'PORT ',I2,' IS BY ATTACHMENT',I3)                      ESP08010
  132 CONTINUE                                                          ESP08020
  131 CONTINUE                                                          ESP08030
      IF(NF.EQ.1)NFM1=NFM                                               ESP08040
      IF(NF.EQ.2)NFM2=NFM                                               ESP08050
      IF(NF.EQ.1)SN1=SN                                                 ESP08060
      IF(NF.EQ.2)SN2=SN                                                 ESP08070
  127 CONTINUE                                                          ESP08080
 1226 CONTINUE                                                          ESP08090
C                                                                       ESP08100
C     WRITE OUT PARAMETERS OF FREQUENCY SWEEP                           ESP08110
C                                                                       ESP08120
      IF(INDZI.NE.0)THEN                                                ESP08130
      WRITE(6,3030)INDZI,FMC1,FMC2,DFZI,DFF                             ESP08140
 3030 FORMAT(/5X,'PARAMETERS OF FREQUENCY SWEEP COMPUTATION'/           ESP08150
     2 3X,'INTERPOLATION METHOD: INDZI = ',I3/                          ESP08160
     2 3X,'BEGINNING FREQUENCY (MHZ) = ',F9.3/                          ESP08170
     3 3X,'ENDING FREQUENCY (MHZ) = ',F9.3/                             ESP08180
     4 3X,'FREQUENCY INTERVAL FOR COMPUTATION OF Z (MHZ) = ',F9.3/      ESP08190
     5 3X,'FREQUENCY INTERVAL FOR MM FIELD COMPUTATIONS (MHZ) = ',F9.3)ESP08200
      IF(IABS(IRS12).EQ.1)WRITE(6,3080)THRD,PHRD                        ESP08210
 3080 FORMAT(3X,'RADIATION ANGLE: THETA =',F6.1,'  PHI =',F6.1,' DEG')  ESP08220
      IF(IABS(IRS12).EQ.2)WRITE(6,3090)THINC,PHINC                      ESP08230
 3090 FORMAT(3X,'INCIDENT ANGLE: THETA =',F6.1,'  PHI =',F6.1,' DEG')   ESP08240
      IF(IABS(IRS12).EQ.2)WRITE(6,3100)THRD,PHRD                        ESP08250
 3100 FORMAT(3X,'SCATTERING ANGLE: THETA =',F6.1,'  PHI =',F6.1,        ESP08260
     &' DEG')                                                           ESP08270
      ENDIF                                                             ESP08280
      IF(NGO.EQ.0)GOTO600                                               ESP08290
      NFZ=0                                                             ESP08300
 3010 IF(INDZI.NE.0)THEN                                                ESP08310
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      NFZ=NFZ+1                                                          ESP08320
      FMC=FMC1+(NFZ-1)*DFZI                                              ESP08330
      WV=300.0/FMC                                                       ESP08340
      XK=2.0*PI/WV                                                       ESP08350
      FHZ=FMC*1.0E6                                                      ESP08360
      GAM=CMPLX(0.0,XK)                                                  ESP08370
      Q=0.001*WV                                                         ESP08380
      ENDIF                                                              ESP08390
C                                                                        ESP08400
C     COMPUTE IMPEDANCE MATRIX                                           ESP08410
C                                                                        ESP08420
C     READ IN IMPEDANCE MATRIX IF IRDZM NOT ZERO                         ESP08430
      IF(IRDZM.LT.1)GOTO631                                              ESP08440
      IF(IFIL.EQ.0)READ(12)(ZT(I),I=1,NZT)                               ESP08450
      IF(IFIL.EQ.1)THEN                                                  ESP08460
      DO 777 J=1,NTOT                                                    ESP08470
      DO 777 I=1,NTOT                                                    ESP08480
777   READ(12)ZTF(I,J)                                                   ESP08490
      END IF                                                             ESP08500
 631  CONTINUE                                                           ESP08510
      IF(IRDZM.EQ.3)GOTO276                                              ESP08520
C                                                                        ESP08530
C     IF A FREQUENCY SWEEP IS BEING MADE SCALE THE IMAGINARY PART OF     ESP08540
C     THE PLATE SHEET ADMITTANCE BY THE FREQUENCY                        ESP08550
C                                                                        ESP08560
      DO636NPL=1,NPLTS                                                   ESP08570
      ZSHTF(NPL)=ZSHT(NPL)                                               ESP08580
      IF(INDZI.EQ.0)GOTO636                                              ESP08590
      IF(ABS(AIMAG(ZSHT(NPL))).LE.1.0E-34)GOTO636                        ESP08600
      YSHT=1.0/ZSHT(NPL)                                                 ESP08610
      FRATIO=FMC/FMC1                                                    ESP08620
      YSHTF=CMPLX(REAL(YSHT),FRATIO*AIMAG(YSHT))                         ESP08630
      ZSHTF(NPL)=1.0/YSHTF                                               ESP08640
 636  CONTINUE                                                           ESP08650
C  SUBROUTINE ZTOTZ: COMPUTES IMPEDANCE MATRIX ZT, OR ZTF, AND IS       ESP08660
C  LOCATED IN ESP4SUBS FORTRAN                                           ESP08670
      CALL ZTOTZ(IA,IB,INM,ISC,I1,I2,I3,JA,JB,MD,NWR,ND,                 ESP08680
     2NM,NP,CGD,SGD,D,X,Y,Z,ZLD,NPLTS,NAT,ZS,IRDZM,ZLDA,                ESP08690
     3PA,PB,NSA,NPLA,PCN,IPL,IPLM,BDSK,ZT,ZTF,NM12N,NM23N,ICN,          ESP08700
     4NDNPLT,NOVT,INT,INTP,INTD,CMM,ERVSR,RMIN,DR,IAT,IPN,              ESP08710
     5IQUAD,NCNRS,IFIL,IREC,ICC,IERVSR,PDIST,MPLA,MPLB,PSZ,ZSHTF,SEGMX) ESP08720
 276  CONTINUE                                                           ESP08730
C                                                                        ESP08740
C     IF INDZI = 3, FORM AND STORE EFFECTIVE INVERSE OF Z                ESP08750
C                                                                        ESP08760
C     IF(INDZI.EQ.3)THEN                                                 ESP08770
C     CJ(1)=(1.0,0.0)                                                    ESP08780
C     IF(IFIL.EQ.0) CALL SQROT(ZT,CJ,0,1,NTOT)                           ESP08790
C     CJ(1)=(1.0,0.0)                                                    ESP08800
C     IF(IFIL.EQ.1) CALL CROUT(ZTF,CJ,IDZTF,1,0,1,NTOT)                  ESP08810
C     ENDIF                                                              ESP08820
      IF(INDZI.NE.0)THEN                                                 ESP08830
      IF(I2468.EQ.0)IZC(NFZ)=NFZ                                         ESP08840
      IF(I2468.EQ.2468)THEN                                              ESP08850
      DO3250III=1,3                                                      ESP08860
      IF(IZC(III).EQ.1)THEN                                              ESP08870
      IZNIT=III                                                          ESP08880
      IZC(III)=3                                                         ESP08890
      ELSE                                                               ESP08900
      IZC(III)=IZC(III)-1                                                ESP08910
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      ENDIF                                                              ESP08920
 3260 CONTINUE                                                           ESP08930
      ENDIF                                                              ESP08940
C                                                                        ESP08950
C     IZC(I) = INTERPOLATING POINT NUMBER OF I ENTRY IN ZT OR ZTF ARRAYESP08960
C                                                                        ESP08970
      DO3020J=1,NTOT                                                     ESP08980
        IF(IFIL.EQ.0)JJ=J                                                ESP08990
        IF(IFIL.EQ.1)JJ=1                                                ESP09000
      DO3020I=JJ,NTOT                                                    ESP09010
        IF(IFIL.EQ.0)THEN                                                ESP09020
        IJN=IJ(I,J,NTOT)                                                 ESP09030
        IF(I2468.EQ.0)ZTIN(NFZ,IJN)=ZT(IJN)                              ESP09040
        IF(I2468.EQ.2468)ZTIN(IZNXT,IJN)=ZT(IJN)                         ESP09050
        END IF                                                           ESP09060
        IF(IFIL.EQ.1.AND.I2468.EQ.0)ZTFIN(NFZ,I,J)=ZTF(I,J)              ESP09070
        IF(IFIL.EQ.1.AND.I2468.EQ.2468)ZTFIN(IZNXT,I,J)=ZTF(I,J)         ESP09080
 3020   CONTINUE                                                         ESP09090
        ENDIF                                                            ESP09100
C       WRITE OUT IMPEDANCE MATRIX.                                      ESP09110
        IF(IWRZM.LE.0)GOTO632                                            ESP09120
C       OPEN(UNIT=1,NAME='ZMAT.DAT',TY.E='UNKNOWN',FORM= UNFORMATTED')   ESP09130
        IF(IFIL.EQ.0)WRITE(12)(ZT(I),I=1,NZT)                            ESP09140
        IF(IFIL.EQ.1)THEN                                                ESP09150
        DO 778 J=1,NTOT                                                  ESP09160
        DO 778 I=1,NTOT                                                  ESP09170
778     WRITE(12)ZTF(I,J)                                                ESP09180
        END IF                                                           ESP09190
C       CLOSE(UNIT=1)                                                    ESP09200
  632   CONTINUE                                                         ESP09210
        IF(IWRZT.GT.0.AND.IFIL.EQ.0)WRITE(6,634)FMC                      ESP09220
  634   FORMAT(//3X,'LOWER TRIANGULAR PART OF SYMMETRIC IMPEDANCE',      ESP09230
     2  ' MATRIX AT ',F9.3,' (MHZ)'//5X,'I',5X,'J',12X,'Z(I,J)'/)       ESP09240
        IF(IWRZT.GT.0.AND.IFIL.EQ.1)WRITE(6,635)FMC                      ESP09250
  635   FORMAT(//5X,'IMPEDANCE MATRIX AT ',F9.3,' (MHZ)'//              ESP09260
     2  5X,'I',6X,'J',12X,'Z(I,J)'/)                                    ESP09270
       DO1234J=1,NTOT                                                    ESP09280
        IF(IFIL.EQ.0)JJ=J                                                ESP09290
        IF(IFIL.EQ.1)JJ=1                                                ESP09300
       DO1234I=JJ,NTOT                                                   ESP09310
        IF(IFIL.EQ.0)THEN                                                ESP09320
       IJN=IJ(I,J,NTOT)                                                  ESP09330
        IF(IWRZT.GT.0)WRITE(6,1233)I,J,ZT(IJN)                           ESP09340
        END IF                                                           ESP09350
        IF(IFIL.EQ.1.AND.IWRZT.GT.0.AND.J.EQ.J)WRITE(6,1233)I,J,ZTF(I,J)ESP09360
 1233 FORMAT(2I6,2E15.5)                                                 ESP09370
 1234 CONTINUE                                                           ESP09380
        IF(I2468.EQ.2468)GOTO3260                                        ESP09390
        IF(INDZI.NE.0.AND.NFZ.LT.3)GOTO3010                              ESP09400
        NFFS=0                                                           ESP09410
        NFFS=NFFS+1                                                      ESP09420
 3260   CONTINUE                                                         ESP09430
 3050   IF(INDZI.NE.0)THEN                                               ESP09440
        IF(NFFS.EQ.1)THEN                                                ESP09450
        IF(IRS12.EQ.1.AND.RF.LT.0.0)THEN                                 ESP09460
        WRITE(6,3110)                                                    ESP09470
 3110   FORMAT(//3X,'FREQUENCY SWEEP OF ANTENNA IMPEDANCE, '            ESP09480
     2  'EFFICIENCY, AND FAR-ZONE GAIN'/                                 ESP09490
     2  2X,'F(MHZ)',12X,'ZIN(OHMS)',8X,'% EFF',3X,'GTHETA',2X,          ESP09500
     3  ' GPHI ',2X,'GTHETA',2X,' GPHI ')                                ESP09510
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      WRITE(6,3112)                                                    ESP09620
 3112 FORMAT(45X,'***MAG. (DB)*** **PHASE (DEG)**'/)                   ESP09630
      ENDIF                                                            ESP09640
      IF(IRS12.EQ.1.AND.RF.GE.0.0)THEN                                 ESP09650
      WRITE(6,3113)RF                                                  ESP09660
 3113 FORMAT(//3X,'FREQUENCY SWEEP OF ANTENNA IMPEDANCE, '             ESP09670
     2 'EFFICIENCY, AND NEAR-ZONE GAIN'/                               ESP09680
     3 3X,'PATTERN RADIUS, RF = ',F11.5,' METERS'/                     ESP09690
     2 2X,'F(MHZ)',12X,'ZIN(OHMS)',8X,'% EFF',3X,'GTHETA',2X,         ESP09700
     3 ' GPHI ',2X,' GRAD ',2X,'GTHETA',2X,' GPHI ',2X,' GRAD ')      ESP09710
      WRITE(6,3114)                                                    ESP09720
 3114 FORMAT(45X,'**********MAG. (DB)********** **********PHASE (DEG)**********'/) ESP09730
      ENDIF                                                            ESP09740
      ENDIF                                                            ESP09750
C                                                                      ESP09760
C     QUADRATIC INTERPOLATE ZTIN OR ZTFIN IMPEDANCE MATRIX ARRAYS      ESP09770
C     TO FIND THE IMPEDANCE MATRIX AT THIS FMC                         ESP09780
C                                                                      ESP09790
      II2=1                                                            ESP09800
C     IF(INDZI.EQ.3)II2=2                                              ESP09810
      DFFT=(NFFS-1)*DFF                                                ESP09820
      FMC=FMC1+DFFT                                                    ESP09830
C      TYPE*,NFFS,FMC                                                  ESP09840
C     RE-COMPUTE FREQ. DEPENDENT QUANTITIES                            ESP09850
      WV=300.0/FMC                                                     ESP09860
      XK=2.0*PI/WV                                                     ESP09870
      FHZ=FMC*1.0E6                                                    ESP09880
      GAM=CMPLX(0.0,XK)                                                ESP09890
      Q=0.001*WV                                                       ESP09900
      DO 3180 J=1,NM                                                   ESP09910
      IF(N.EQ.0)GOTO3180                                               ESP09920
      K=IA(J)                                                          ESP09930
      L=IB(J)                                                          ESP09940
      D(J)=SQRT((X(K)-X(L))**2+(Y(K)-Y(L))**2+(Z(K)-Z(L))**2)          ESP09950
      EGD=CEXP(GAM*D(J))                                               ESP09960
      SGD(J)=(EGD-1.0/EGD)/2.0                                         ESP09970
      CGD(J)=(EGD+1.0/EGD)/2.0                                         ESP09980
 3180 CONTINUE                                                         ESP09990
C                                                                      ESP10000
      II2=1.50*DFFT/DFZI                                               ESP10010
      IF(II2.LT.2)II2=2                                                ESP10020
      IF(II2.GT.NFZI-1)II2=NFZI-1                                      ESP10030
      IF(II2.NE.II2LST)THEN                                            ESP10040
      I2468=2468                                                       ESP10050
      II2LST=II2                                                       ESP10060
      GOTO3010                                                         ESP10070
      ENDIF                                                            ESP10080
      II1=II2-1                                                        ESP10090
      II3=II2+1                                                        ESP10100
      DO3270III=1,3                                                    ESP10110
      IF(IZC(III).EQ.1)JJ1=III                                         ESP10120
      IF(IZC(III).EQ.2)JJ2=III                                         ESP10130
      IF(IZC(III).EQ.3)JJ3=III                                         ESP10140
 3270 CONTINUE                                                         ESP10150
      FM1=FMC1+(II1-1)*DFZI                                            ESP10160
      FM2=FMC1+(II2-1)*DFZI                                            ESP10170
      FM3=FMC1+(II3-1)*DFZI                                            ESP10180
      CL1=ALOG(FM1)                                                    ESP10190
      CL2213=-ALOG(FM2**2/(FM1*FM3))                                   ESP10200
      CL21=ALOG(FM2/FM1)                                               ESP10210
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      WV1=300.0/FM1                                                    ESP10120
      XK1=2.0*PI/WV1                                                   ESP10130
      WV2=300.0/FM2                                                    ESP10140
      XK2=2.0*PI/WV2                                                   ESP10150
      WV3=300.0/FM3                                                    ESP10160
      XK3=2.0*PI/WV3                                                   ESP10170
      DFZI2=DFZI**2                                                    ESP10180
      EL1=0.5*(FMC-FM2)*(FMC-FM3)/DFZI2                                ESP10190
      EL2=-(FMC-FM1)*(FMC-FM3)/DFZI2                                   ESP10200
      EL3=0.5*(FMC-FM1)*(FMC-FM2)/DFZI2                                ESP10210
      IF(IWRZT.GT.0.AND.IFIL.EQ.0)WRITE(6,634)FMC                      ESP10220
      IF(IWRZT.GT.0.AND.IFIL.EQ.1)WRITE(6,635)FMC                      ESP10230
      WVMIN=300.0/FMC2                                                 ESP10240
      RIJ=0.0                                                          ESP10250
     DO3060J=1,NTOT                                                    ESP10260
      IF(INDZI.EQ.2)THEN                                               ESP10270
C     FIND CENTER COOR. OF MODE J                                      ESP10280
      IF(J.LE.NWR)THEN                                                 ESP10290
      I2J=I2(J)                                                        ESP10300
      XCJ=X(I2J)                                                       ESP10310
      YCJ=Y(I2J)                                                       ESP10320
      ZCJ=Z(I2J)                                                       ESP10330
      ENDIF                                                            ESP10340
      IF(J.GT.NWR.AND.J.LE.NWR+NPLTM)THEN                              ESP10350
      JJJ=J-NWR                                                        ESP10360
      XCJ=0.5*(PA(JJJ,1,1)+PA(JJJ,4,1))                                ESP10370
      YCJ=0.5*(PA(JJJ,1,2)+PA(JJJ,4,2))                                ESP10380
      ZCJ=0.5*(PA(JJJ,1,3)+PA(JJJ,4,3))                                ESP10390
      ENDIF                                                            ESP10400
      IF(J.GT.NWR+NPLTM)THEN                                           ESP10410
      JJJ=J-NPLTM-NWR                                                  ESP10420
      JSG=NSA(JJJ)                                                     ESP10430
      IF(JSG.LE.NM)I2J=IA(JSG)                                         ESP10440
      IF(JSG.GT.NM)I2J=JB(JSG-NM)                                      ESP10450
      XCJ=X(I2J)                                                       ESP10460
      YCJ=Y(I2J)                                                       ESP10470
      ZCJ=Z(I2J)                                                       ESP10480
      ENDIF                                                            ESP10490
      ENDIF                                                            ESP10500
      IF(IFIL.EQ.0)JJ=J                                                ESP10510
      IF(IFIL.EQ.1)JJ=1                                                ESP10520
     DO3060I=JJ,NTOT                                                   ESP10530
C                                                                      ESP10540
C     IF INDZI = 2, FACTOR OUT THE EXP(-J*K*R) DEPENDENCE OF THE       ESP10550
C     ELEMENTS IN THE IMPEDANCE MATRIX BEFORE INTERPOLATING            ESP10560
C                                                                      ESP10570
      CEXP1=(1.0,0.0)                                                  ESP10580
      CEXP2=(1.0,0.0)                                                  ESP10590
      CEXP3=(1.0,0.0)                                                  ESP10600
      CEXPK=(1.0,0.0)                                                  ESP10610
      IF(INDZI.EQ.2)THEN                                               ESP10620
C     FIND CENTER COOR. OF MODE I                                      ESP10630
      IF(I.LE.NWR)THEN                                                 ESP10640
      I2J=I2(I)                                                        ESP10650
      XCI=X(I2J)                                                       ESP10660
      YCI=Y(I2J)                                                       ESP10670
      ZCI=Z(I2J)                                                       ESP10680
      ENDIF                                                            ESP10690
      IF(I.GT.NWR.AND.I.LE.NWR+NPLTM)THEN                              ESP10700
      JJJ=I-NWR                                                        ESP10710
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      XCI=0.5*(PA(JJJ,1,1)+PA(JJJ,4,1))                                 ESP10720
      YCI=0.5*(PA(JJJ,1,2)+PA(JJJ,4,2))                                 ESP10730
      ZCI=0.5*(PA(JJJ,1,3)+PA(JJJ,4,3))                                 ESP10740
      ENDIF                                                             ESP10750
      IF(I.GT.NWR+NPLTM)THEN                                            ESP10760
      JJJ=I-NPLTM-NWR                                                   ESP10770
      JSG=NSA(JJJ)                                                      ESP10780
      IF(JSG.LE.NM)I2J=IA(JSG)                                          ESP10790
      IF(JSG.GT.NM)I2J=IB(JSG-NM)                                       ESP10800
      XCI=X(I2J)                                                        ESP10810
      YCI=Y(I2J)                                                        ESP10820
      ZCI=Z(I2J)                                                        ESP10830
      ENDIF                                                             ESP10840
      RIJ=SQRT((XCJ-XCI)**2+(YCJ-YCI)**2+(ZCJ-ZCI)**2)                  ESP10850
      IF(RIJ/WVMIN.GT.0.501)THEN                                        ESP10860
      CEXP1=CEXP(-XJ*(XK1-XK2)*RIJ)                                     ESP10870
      CEXP2=CEXP(-XJ*(XK2-XK2)*RIJ)                                     ESP10880
      CEXP3=CEXP(-XJ*(XK3-XK2)*RIJ)                                     ESP10890
      CEXPK=CEXP(-XJ*(XK-XK2)*RIJ)                                      ESP10900
      ENDIF                                                             ESP10910
      ENDIF                                                             ESP10920
      IF(IFIL.EQ.0)THEN                                                 ESP10930
     IJN=IJ(I,J,NTOT)                                                   ESP10940
      FAC1=CEXP1                                                        ESP10950
      FAC2=CEXP2                                                        ESP10960
      FAC3=CEXP3                                                        ESP10970
      FACK=CEXPK                                                        ESP10980
      ZT(IJN)=EL1*ZTIN(JJ1,IJN)/FAC1+EL2*ZTIN(JJ2,IJN)/FAC2+            ESP10990
     2  EL3*ZTIN(JJ3,IJN)/FAC3                                          ESP11000
      ZT(IJN)=ZT(IJN)*FACK                                              ESP11010
      IF(INDZI.EQ.2.AND.RIJ/WVMIN.LE.0.501.AND.I.LE.NWR.AND.J.LE.NWR)   ESP11020
     2  THEN                                                            ESP11030
      XXX1=AIMAG(ZTIN(JJ1,IJN))                                         ESP11040
      XXX2=AIMAG(ZTIN(JJ2,IJN))                                         ESP11050
      XXX3=AIMAG(ZTIN(JJ3,IJN))                                         ESP11060
      BBB=(XXX3-2.0*XXX2+XXX1)/CL2213                                   ESP11070
      CCC=(XXX2-XXX1-BBB*CL21)/DFZI                                     ESP11080
      AAA=XXX1-BBB*CL1-CCC*FM1                                          ESP11090
      XXX=AAA+BBB*ALOG(FMC)+CCC*FMC                                     ESP11100
      ZT(IJN)=CMPLX(REAL(ZT(IJN)),XXX)                                  ESP11110
      ENDIF                                                             ESP11120
      IF(IWRZT.GT.0)WRITE(6,1233)I,J,ZT(IJN)                            ESP11130
      END IF                                                            ESP11140
      IF(IFIL.EQ.1)THEN                                                 ESP11150
      FAC1=CEXP1                                                        ESP11160
      FAC2=CEXP2                                                        ESP11170
      FAC3=CEXP3                                                        ESP11180
      FACK=CEXPK                                                        ESP11190
      ZTF(I,J)=EL1*ZTFIN(JJ1,I,J)/FAC1+EL2*ZTFIN(JJ2,I,J)/FAC2+         ESP11200
     2  EL3*ZTFIN(JJ3,I,J)/FAC3                                         ESP11210
      ZTF(I,J)=ZTF(I,J)*FACK                                            ESP11220
      IF(INDZI.EQ.2.AND.RIJ/WVMIN.LE.0.501)THEN                         ESP11230
      IF(IWRZT.GT.0)WRITE(6,1233)I,J,ZTF(I,J)                           ESP11240
      XXX1=AIMAG(ZTFIN(JJ1,I,J))                                        ESP11250
      XXX2=AIMAG(ZTFIN(JJ2,I,J))                                        ESP11260
      XXX3=AIMAG(ZTFIN(JJ3,I,J))                                        ESP11270
      BBB=(XXX3-2.0*XXX2+XXX1)/CL2213                                   ESP11280
      CCC=(XXX2-XXX1-BBB*CL21)/DFZI                                     ESP11290
      AAA=XXX1-BBB*CL1-CCC*FM1                                          ESP11300
      XXX=AAA+BBB*ALOG(FMC)+CCC*FMC                                     ESP11310
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          ZTF(I,J)=CMPLX(REAL(ZTF(I,J)),XXX)                    ESP11320
          ENDIF                                                 ESP11330
          IF(IWRZT.GT.0)WRITE(6,1233)I,J,ZTF(I,J)               ESP11340
          ENDIF                                                 ESP11350
 3060 CONTINUE                                                  ESP11360
          ENDIF                                                 ESP11370
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```
C                                                                       ESP11380
C       COMPUTE COUPLING BETWEEN TWO WIRE PORTS                         ESP11390
C                                                                       ESP11400
        IF(ICP.EQ.1) CALL COUPLE(ZT,ZTF,NFM1,NFM2,SN1,SN2,I12,V,        ESP11410
     2  NTOT,IFIL,ICC)                                                  ESP11420
      IF(ISCAT.GE.1) GOTO 601                                           ESP11430
C COMPUTE CONSTANT VECTOR & SOLVE SYSTEM                                ESP11440
        IF(IWR.GT.0)WRITE(6,576)                                        ESP11450
  576   FORMAT(//5X,'ANTENNA MODAL CURRENTS'/3X,'MODE',3X,              ESP11460
     2  'REL MAG',6X,'ABS MAG',5X,'PHASE',10X,'*** COMPLEX ***'/)       ESP11470
        IF(IANT.EQ.0)GOTO600                                            ESP11480
C                                                                       ESP11490
C       FOR ANTENNA PROBLEMS, SET UP RHS VECTOR AND SOLVE FOR CURRENTS  ESP11500
C                                                                       ESP11510
      CALL ANTV(I1,I2,I3,IA,IB,IWR,JA,JB,NM,ZT,IFIL,                    ESP11520
     &  ICC,ZTF,CJP,CG,VG,Y11,Z11,VIN,NGEN,NWR,NPLTM,NAT,VGA,PIN,       ESP11530
     2  A,CMM,D,DISS,GAM,SGD,ZLD,ZS,ZLDA,INM,MD,ND,NSA,I12)             ESP11540
C                                                                       ESP11550
C       IF THERE IS ONLY ONE GENERATOR COMPUTE INPUT IMPEDANCE          ESP11560
C                                                                       ESP11570
        ZIN=(0.0,0.0)                                                   ESP11580
        YIN=(0.0,0.0)                                                   ESP11590
        IF(NGEN.EQ.1)THEN                                               ESP11600
        YIN=Y11/(CABS(VIN))**2                                          ESP11610
        ZIN=1.0/YIN                                                     ESP11620
        ENDIF                                                           ESP11630
        I12=2                                                           ESP11640
        PRAD=PIN-DISS                                                   ESP11650
        EFF=100.0*PRAD/PIN                                              ESP11660
C       IF(INDZI.EQ.0)WRITE(6,513) Y11,Z11,EFF                          ESP11670
  513 FORMAT(/3X,'INPUT ADMITTANCE(MHOS) = ',F10.6,' J ',F10.6/         ESP11680
     2  3X,'INPUT IMPEDANCE(OHMS) = ',F10.3,' J ',F10.3/,               ESP11690
     3  3X,'EFFICIENCY (PERCENT) = ',F7.3/)                             ESP11700
        IF(INDZI.EQ.0.AND.NGEN.EQ.1)WRITE(6,513) YIN,ZIN,EFF            ESP11710
        IF(INDZI.EQ.0.AND.NGEN.NE.1)WRITE(6,514)NGEN,EFF                ESP11720
  514   FORMAT(/3X,'INPUT IMPEDANCE AND ADMITTANCE ONLY COMPUTED IF',   ESP11730
     2  ' WIRE HAS ONE GENERATOR'/3X,'NUMBER OF GENERATORS = ',I4/      ESP11740
     3  3X,'EFFICIENCY (PERCENT) = ',F7.3/)                             ESP11750
  501 CONTINUE                                                          ESP11760
      IF(IFF.NE.1) GOTO 599                                             ESP11770
  572 FORMAT(//3X,'ANTENNA PROBLEM, ISCAT = ',I5)                       ESP11780
  573 FORMAT(//3X,'BACKSCATTERING, ISCAT = ',I5)                        ESP11790
  574 FORMAT(//3X,'BISTATIC SCATTERING, ISCAT = ',I5)                   ESP11800
  577   FORMAT(//3X,'FORWARD SCATTERING, ISCAT = ',I5)                  ESP11810
        IF(INDZI.EQ.0)THEN                                              ESP11820
      IF(ISCAT.EQ.0)WRITE(6,572)ISCAT                                   ESP11830
      IF(ISCAT.EQ.1)WRITE(6,573)ISCAT                                   ESP11840
      IF(ISCAT.EQ.2)WRITE(6,574)ISCAT                                   ESP11850
        IF(ISCAT.EQ.3)WRITE(6,577)ISCAT                                 ESP11860
        ENDIF                                                           ESP11870
      IF(ISCAT.NE.0)GO TO 601                                           ESP11880
C                                                                       ESP11890
C GET INPUT FOR PATTERNS                                                ESP11900
C ANTENNA PROBLEM ISCAT=0                                               ESP11910
C                                                                       ESP11920
  950 DTH=PI/180.                                                       ESP11930
      IF (IFE .NE. 1) GOTO 901                                          ESP11940
C                                                                       ESP11950
C       PERFORM ELEVATION PLANE RADIATION PLANE PATTERN                 ESP11960
C                                                                       ESP11970
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      PHI=PHFE*DTH                                                      ESP11980
CC      NPTS=360/FNDFE+1.5                                              ESP11990
CC        XNDFE=360/(NPTS-1)                                            ESP12000
      NPTS=ELRANG/FNDFE+1.5
CC**SET XNDFE=0. INITIALLY AND CHECK NPTS.GT.1 (AJF)
      XNDFE=0.
      IF(NPTS.GT.1)XNDFE=ELRANG/(NPTS-1)
        IEA=1                                                           ESP12010
        IF(NPLOTS.GT.0.AND.INDZI.EQ.0)WRITE(8,338)IEA,NPTS,PHFE         ESP12020
  338   FORMAT(1X,2(I3,1X),2X,F7.2)                                     ESP12030
        IF(INDZI.NE.0)THEN                                              ESP12040
        PHI=PHRD*DTH                                                    ESP12050
        NPTS=1                                                          ESP12060
        ENDIF                                                           ESP12070
      DO 903 I=1,NPTS                                                   ESP12080
CC***ADDED ELMIN TO THETA IN NEXT LINE TO START AT ARB. OBS. PT.
      THETA=ELMIN*DTH+(I-1)*DTH*XNDFE                                   ESP12090
        IF(THETA.GT.1.00001*PI)THEN                                     ESP12100
        THETA=2.0*PI-THETA                                              ESP12110
        IF(I9999.NE.9999)PHI=PHI+PI                                     ESP12120
        I9999=9999                                                      ESP12130
        ENDIF                                                           ESP12140
        IF(INDZI.NE.0)THETA=THRD*DTH                                    ESP12150
C       CALL SORTB(IA,IB,I1,I2,I3,NWR,NM,A,CGD,SGD,FHZ,D,               ESP12160
C     & 0,I12,ISCAT,ZTF,ZT,IFIL,ICC,ETT,EPP,                            ESP12170
C     & X,Y,Z,NPLTS,NAT,PA,PB,NSA,NPLA,PCN,BDSK,IQUAD,                  ESP12180
C     & NPLTM,IPL,IPLM,CJP,CJT,ETTS,EPPS,ETPS,EPTS,THETA,PHI,JA,JB,     ESP12190
C     & SCSP,SCST,SPPM,SPTM,STPM,STTM,IMAGE,ICN,NDNPLT)                 ESP12200
      CALL SORTBN(IA,IB,I1,I2,I3,NWR,NM,A,CGD,SGD,FHZ,D,                ESP12210
     & 0,I12,ISCAT,ZTF,ZT,IFIL,ICC,ETT,EPP,INTP,INTD,                   ESP12220
     & X,Y,Z,NPLTS,NAT,PA,PB,NSA,NPLA,PCN,BDSK,IQUAD,                   ESP12230
     & NPLTM,IPL,IPLM,CJP,CJT,ETTS,EPPS,ETPS,EPTS,THETA,PHI,JA,JB,      ESP12240
     & SCSP,SCST,SPPM,SPTM,STPM,STTM,IMAGE,ICN,NDNPLT,                  ESP12250
     & RF,EXN,EYN,EZN,EXT,EYT,EZT,EXP,EYP,EZP,ERRS,ETRS,EPRS,STRM,SPRM) ESP12260
      PET(I)=PHS(ETTS)                                                  ESP12270
      PEP(I)=PHS(EPPS)                                                  ESP12280
      ETE(I)=CABS(ETTS)**2/((1.0,0.0)*30.0*PIN)                         ESP12290
      EPE(I)=CABS(EPPS)**2/((1.0,0.0)*30.0*PIN)                         ESP12300
      AET=AMP(ETE(I))                                                   ESP12310
      AEP=AMP(EPE(I))                                                   ESP12320
        AER=0.0                                                         ESP12330
        PER(I)=0.0                                                      ESP12340
        IF(RF.GT.0.0)THEN                                               ESP12350
        PER(I)=PHS(ERRS)                                                ESP12360
        ERE(I)=CABS(ERRS)**2/((1.0,0.0)*30.0*PIN)                       ESP12370
        AER=AMP(ERE(I))                                                 ESP12380
        ENDIF                                                           ESP12390
        IF(NPLOTS.GT.0.AND.INDZI.EQ.0)WRITE(8,333)DB(AET),PET(I),       ESP12400
     2  DB(AEP),PEP(I),DB(AER),PER(I)                                   ESP12410
        II=I                                                            ESP12420
  903   CONTINUE                                                        ESP12430
        IF(INDZI.NE.0.AND.RF.LT.0.0)THEN                                ESP12440
        WRITE(6,3120)FMC,ZIN,EFF,DB(AET),DB(AEP),PET(II),PEP(II)        ESP12450
        WRITE(10,3125)FMC,ZIN,EFF,DB(AET),DB(AEP),PET(II),PEP(II)       ESP12460
 3120   FORMAT(1X,F9.3,2X,E10.4,' J ',E10.4,2X,F6.1,2(2X,F6.2),         ESP12470
     2  2(2X,F6.1))                                                     ESP12480
 3125   FORMAT(1X,F9.3,2X,E10.4,2X,E10.4,2X,F6.1,2(2X,F6.2),           ESP12490
     2  2(2X,F6.1))                                                     ESP12500
        GOTO3070                                                        ESP12510
        ENDIF                                                           ESP12520
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      IF(INDZI.NE.0.AND.RF.GE.0.0)THEN                                  ESP12530
      WRITE(6,3121)FMC,ZIN,EFF,DB(AET),DB(AEP),DB(AER),                 ESP12540
     2  PET(II),PEP(II),PER(II)                                         ESP12550
      WRITE(10,3126)FMC,ZIN,EFF,DB(AET),DB(AEP),DB(AER),                ESP12560
     2  PET(II),PEP(II),PER(II)                                         ESP12570
 3121  FORMAT(1X,F9.3,2X,E10.4,' J ',E10.4,2X,F6.1,3(2X,F6.2),           ESP12580
     2  3(2X,F6.1))                                                     ESP12590
 3126  FORMAT(1X,F9.3,2X,E10.4,2X,E10.4,2X,F6.1,3(2X,F6.2),             ESP12600
     2  3(2X,F6.1))                                                     ESP12610
      GOTO3070                                                          ESP12620
      ENDIF                                                             ESP12630
      IF(RF.LE.0.0)THEN                                                 ESP12640
     WRITE(6,904) PHFE                                                  ESP12650
904   FORMAT(///,' FAR-ZONE GAIN ELEVATION PLANE PATTERN. PHI =',F6.1,   ESP12660
     2  ' DEG.'/)                                                       ESP12670
      WRITE(6,902)                                                      ESP12680
 902  FORMAT(' (DEG)   **MAG (DB)**   *PHASE (DEG)*'/                   ESP12690
     2  ' THETA  GTHETA   GPHI   GTHETA    GPHI'/)                      ESP12700
      ELSE                                                              ESP12710
     WRITE(6,804) RF,PHFE                                               ESP12720
804   FORMAT(///,' NEAR-ZONE GAIN ELEVATION PLANE PATTERN.'/3X,          ESP12730
     2  'R = ',F11.6,1X,'METERS    PHI =',F6.1,' DEG.'/)                ESP12740
     WRITE(6,805)                                                       ESP12750
 805  FORMAT(' (DEG)  ******MAG (DB)********  *****PHASE (DEG)*****'/   ESP12760
     2  ' THETA  GTHETA   GPHI      GR   GTHETA    GPHI    GR')        ESP12770
      ENDIF                                                             ESP12780
     DO 906 I=1,NPTS                                                    ESP12790
CC***ADDED ELMIN IN NEXT LINE TO START AT ARB. OBS. PT.
     XII=ELMIN+(I-1)*XNDFE                                              ESP12800
     AET=AMP(ETE(I))                                                    ESP12810
     AEP=AMP(EPE(I))                                                    ESP12820
      AET=DB(AET)                                                       ESP12830
      AEP=DB(AEP)                                                       ESP12840
      IF(RF.GT.0.0)THEN                                                 ESP12850
      AER=AMP(ERE(I))                                                   ESP12860
      AER=DB(AER)                                                       ESP12870
      WRITE(6,807)XII,AET,AEP,AER,PET(I),PEP(I),PER(I)                  ESP12880
 807  FORMAT(1X,F5.1,3(2X,F6.2),3(2X,F6.1))                             ESP12890
      ELSE                                                              ESP12900
     WRITE(6,907) XII,AET,AEP,PET(I),PEP(I)                             ESP12910
 907 FORMAT(1X,F5.1,2X,F6.2,2X,F6.2,2X,F6.1,2X,F6.1)                    ESP12920
      ENDIF                                                             ESP12930
      ETE(I)=CSQRT(1.0E-20*ETE(I))                                      ESP12940
      EPE(I)=CSQRT(1.0E-20*EPE(I))                                      ESP12950
      IF(RF.GT.0.0)ERE(I)=CSQRT(1.0E-20*ERE(I))                         ESP12960
 906  CONTINUE                                                          ESP12970
 901  CONTINUE                                                          ESP12980
     IF(IPA .NE. 1) GOTO 599                                            ESP12990
C                                                                       ESP13000
C       PERFORM AZIMUTH PLANE RADIATION PATTERN                         ESP13010
C                                                                       ESP13020
     THETA=THFA*DTH                                                     ESP13030
C**NOTE: IN NEXT TWO LINES CHANGED 360 TO AZRANG
     NPTS=AZRANG/FNDFA+1.5                                              ESP13040
CC***SET XNDFA=0. AND CHECK NPTS.GT.1
     XNDFA=0.
      IF(NPTS.GT.1)XNDFA=AZRANG/(NPTS-1)                                ESP13050
      IEA=2                                                             ESP13060
      IF(NPLOTS.GT.0.AND.INDZI.EQ.0)WRITE(6,336)IEA,NPTS,THFA           ESP13070
     DO 911 I=1,NPTS                                                    ESP13080
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```
CC***ADDED AZMIN IN NEXT LINE
      PHI=AZMIN+DTH+(I-1)*DTH*XNDFA                                      ESP13090
C*********************************                                       ESP13100
C       CALL SORTB(IA,IB,I1,I2,I3,NWR,NM,A,CGD,SGD,FHZ,D,                ESP13110
C      & 0,I12,ISCAT,ZTF,ZT,IFIL,ICC,ETT,EPP,                            ESP13120
C      &X,Y,Z,NPLTS,NAT,PA,PB,NSA,NPLA,PCN,BDSK,IQUAD,                   ESP13130
C      &NPLTM,IPL,IPLM,CJP,CJT,ETTS,EPPS,ETPS,EPTS,THETA,PHI,JA,JB,      ESP13140
C      & SCSP,SCST,SPPM,SPTM,STPM,STTM,IMAGE,ICN,NDNPLT)                 ESP13150
       CALL SORTBN(IA,IB,I1,I2,I3,NWR,NM,A,CGD,SGD,FHZ,D,                ESP13160
      & 0,I12,ISCAT,ZTF,ZT,IFIL,ICC,ETT,EPP,INTP,INTD,                   ESP13170
      &X,Y,Z,NPLTS,NAT,PA,PB,NSA,NPLA,PCN,BDSK,IQUAD,                    ESP13180
      &NPLTM,IPL,IPLM,CJP,CJT,ETTS,EPPS,ETPS,EPTS,THETA,PHI,JA,JB,       ESP13190
      & SCSP,SCST,SPPM,SPTM,STPM,STTM,IMAGE,ICN,NDNPLT,                  ESP13200
      & RF,EXN,EYN,EZN,EXT,EYT,EZT,EXP,EYP,EZP,ERRS,ETRS,EPRS,STRM,SPRM) ESP13210
       PET(I)=PHS(ETTS)                                                  ESP13220
       PEP(I)=PHS(EPPS)                                                  ESP13230
       ETAZ(I)=CABS(ETTS)**2/((1.0,0.0)*30.0*PIN)                        ESP13240
       EPAZ(I)=CABS(EPPS)**2/((1.0,0.0)*30.0*PIN)                        ESP13250
       AET=AMP(ETAZ(I))                                                  ESP13260
       AEP=AMP(EPAZ(I))                                                  ESP13270
         AER=0.0                                                         ESP13280
         PER(I)=0.0                                                      ESP13290
         IF(RF.GT.0.0)THEN                                               ESP13300
         PER(I)=PHS(ERRS)                                                ESP13310
         ERAZ(I)=CABS(ERRS)**2/((1.0,0.0)*30.0*PIN)                      ESP13320
         AER=AMP(ERAZ(I))                                                ESP13330
         ENDIF                                                           ESP13340
         IF(NPLOTS.GT.0.AND.INDZI.EQ.0)WRITE(8,333)DB(AET),PET(I),       ESP13350
     2   DB(AEP),PEP(I),DB(AER),PER(I)                                   ESP13360
  911    CONTINUE                                                        ESP13370
         IF(RF.LE.0.0)THEN                                               ESP13380
       WRITE(6,912) THFA                                                 ESP13390
912    FORMAT(////2X,'FAR-ZONE GAIN AZIMUTH PLANE PATTERN.  THETA =',F6.1ESP13400
     2,' DEG.'/)                                                         ESP13410
         WRITE(6,905)                                                    ESP13420
  905    FORMAT(' (DEG)   **MAG (DB)**   *PHASE (DEG)*'/                ESP13430
     2   '  PHI   GTHETA   GPHI   GTHETA    GPHI'/)                     ESP13440
C       WRITE(6,914)                                                    ESP13450
C914    FORMAT(' PHI(DEG)       GTHETA(DB)        GPHI(DB)')            ESP13460
         ELSE                                                            ESP13470
       WRITE(6,808) RF,THFA                                              ESP13480
808    FORMAT(///,' NEAR-ZONE GAIN AZIMUTH PLANE PATTERN.'/3X,           ESP13490
     2  'R = ',F11.5,1X,'METERS    THETA =',F6.1,' DEG.'/)               ESP13500
       WRITE(6,809)                                                      ESP13510
  809   FORMAT(' (DEG)  ******MAG (DB)********  *****PHASE (DEG)*****'/ ESP13520
     2   '  PHI   GTHETA   GPHI      GR   GTHETA    GPHI    GR')        ESP13530
         ENDIF                                                           ESP13540
       DO 913 I=1,NPTS                                                   ESP13550
       XII=AZMIN+(I-1)*XNDFA
       AET=AMP(ETAZ(I))                                                  ESP13570
       AEP=AMP(EPAZ(I))                                                  ESP13580
         AET=DB(AET)                                                     ESP13590
         AEP=DB(AEP)                                                     ESP13600
         IF(RF.GT.0.0)THEN                                               ESP13610
         AER=AMP(ERE(I))                                                 ESP13620
         AER=DB(AER)                                                     ESP13630
         WRITE(6,807)XII,AET,AEP,AER,PET(I),PEP(I),PER(I)                ESP13640
         ELSE                                                            ESP13650
       WRITE(6,907) XII,AET,AEP,PET(I),PEP(I)                            ESP13660
         ENDIF                                                           ESP13670
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      ETAZ(I)=CSQRT(1.0E-20+ETAZ(I))                                    ESP13680
      EPAZ(I)=CSQRT(1.0E-20+EPAZ(I))                                    ESP13690
      ERAZ(I)=CSQRT(1.0E-20+ERAZ(I))                                    ESP13700
  913 CONTINUE                                                          ESP13710
      GOTO599                                                           ESP13720
  601 CONTINUE                                                          ESP13730
C                                                                       ESP13740
C     BACK OR BISTATIC OR FORWARD SCATTERING  ISCAT = 1 OR 2 OR 3.      ESP13750
C                                                                       ESP13760
      IF(INDZI.EQ.0)THEN                                                ESP13770
      IF(RF.LE.0.0)WRITE(6,721)                                         ESP13780
  721 FORMAT(3X,'FAR-ZONE PATTERN')                                     ESP13790
      IF(RF.GT.0.0)WRITE(6,731)RF                                       ESP13800
  731 FORMAT(3X,'NEAR-ZONE PATTERN: R = ',F11.5)                        ESP13810
      IF(IMAGE.EQ.1)WRITE(6,714)                                        ESP13820
  714 FORMAT(3X,'IMAGE WAVE INCLUDED')                                  ESP13830
      IF(ISCAT.EQ.2)WRITE(6,713)THIN,PHIN                               ESP13840
  713 FORMAT(3X,'THETA INC.(DEG.) = ',F6.1/3X,'PHI INC.(DEG.) = ',F6.1ESP13850
     2 //)                                                              ESP13860
      ELSE IF(NFFS.EQ.1) THEN                                           ESP13870
      IF(IRS12.EQ.-2)WRITE(6,714)                                       ESP13880
      WRITE(6,3200)                                                     ESP13890
 3200 FORMAT(//3X,'FREQUENCY SWEEP OF TARGET RCS '/                     ESP13900
     2 12X,'****** MAG. (DB/M**2) ******',                              ESP13910
     3 5X,'******* PHASE (DEG) ********'/                              ESP13920
     4 2X,'F(MHZ)',4X,'STTM',4X,'SPPM',4X,'STPM',4X,'SPTM',             ESP13930
     5 5X,'STTM',4X,'SPPM',4X,'STPM',4X,'SPTM'/)                        ESP13940
      ENDIF                                                             ESP13950
      ISP=0                                                             ESP13960
     DTH=PI/180.0                                                       ESP13970
C     I12=1                                                             ESP13980
      IEA=1                                                             ESP13990
      IF(ISE.EQ.0)GOTO916                                               ESP14000
      PHDG=PHSE                                                         ESP14010
      PANG=PHDG                                                         ESP14020
      NANG=0.5+(ELRANG/FNDSE)                                           ESP14030
     ANGRAN=ELRANG
      GOTO917                                                           ESP14040
  918 IEA=2                                                             ESP14050
      IF(ISA.EQ.0)GOTO916                                               ESP14060
      THDG=THSA                                                         ESP14070
      PANG=THDG                                                         ESP14080
      NANG=0.5+(AZRANG/FNDSA)                                           ESP14090
     ANGRAN=AZRANG
  917 CONTINUE                                                          ESP14100
C**IN LINE BELOW SUBSTITUTED ANGRAN (DEFINED ABOVE) FOR 360.
CC***SET DANG=0. AND CHECK NANG.GT.0
     DANG=0.
      IF(NANG.GT.0)DANG=ANGRAN/NANG                                     ESP14110
     IA1=1                                                              ESP14120
      ISP=ISP+1                                                         ESP14130
      IF(ISCAT.EQ.2.AND.ISP.EQ.1)IA1=0                                  ESP14140
     IA2=1+NANG                                                         ESP14150
      NPTS=IA2                                                          ESP14160
      IF(NPLOTS.GT.0.AND.INDZI.EQ.0)WRITE(8,336)IEA,NPTS,ISCAT,         ESP14170
     2 PANG,THIN,PHIN                                                   ESP14180
  336 FORMAT(1X,3(I3,1X),3(F7.2,2X))                                    ESP14190
      IF(INDZI.NE.0)IA2=1                                               ESP14200
C**NEW LINES TO IMPLEMENT CONSTANT BISTATIC ANGLE OPTION (TARGET ROT.)
C**IT IS ASSUMED THAT THE REFERENCE ANGLE IS THE BISECTOR OF THE
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```
C**BISTATIC ANGLE.  NOTE THAT THE SUM OF THE INCIDENT AND OUTGOING
C**ANGLES DIVIDED BY 2 GIVES THE TARGET ROTATION ANGLE.
      DANGB=0.
      IF(NPTBIS.GT.1)DANGB=BANGRG/(NPTBIS-1)
      DO 1920 IBIS=1,NPTBIS
      IF(IBISC.EQ.1)THIN=-BETA/2.+DANGB*(IBIS-1)
      IF(IBISC.EQ.1)WRITE(6,9278)IBIS,THIN
9278  FORMAT(1X,'IBIS=',I4,' THIN=',F12.3)
      DO 701 IANG=IA1,IA2                                          ESP14210
      CALL GETCP2(ICPUB)
      CPU=ICPUB-ICPU
      WRITE(6,9552)IANG,CPU
9552  FORMAT(1X,'IANG=',I4,2X,'CPU=',F11.2,2X,'SEC.')
CC**ADDED ELMIN,AZMIN TO THDG,PHDG IN NEXT TWO LINES
        IF(IEA.EQ.1)THDG=ELMIN+(IANG-1)*DANG                       ESP14220
        IF(IEA.EQ.2)PHDG=AZMIN+(IANG-1)*DANG                       ESP14230
      IF(IBISC.EQ.1.AND.IEA.EQ.1)THDG=BETA/2.+DANGB*(IBIS-1)
      IF(IBISC.EQ.1.AND.IEA.EQ.2)PHDG=BETA/2.+DANGB*(IBIS-1)
        THETA=THDG*DTH                                             ESP14240
      PHI=PHDG*DTH                                                 ESP14250
        IF(ISCAT.LE.2)ISCT=ISCAT                                   ESP14260
        IF(IANG.EQ.0)ISCT=1                                        ESP14270
        IF(IANG.EQ.0)THETA=THIN*DTH                                ESP14280
        IF(IANG.EQ.0)PHI=PHIN*DTH                                  ESP14290
C       IF(IWR.GT.0.AND.ISCT.EQ.1)WRITE(6,576)                     ESP14300
        III=1                                                      ESP14310
        IF(ISCAT.EQ.3)III=2                                        ESP14320
        DO711IIS=1,III                                             ESP14330
        IF(ISCAT.LE.2)GOTO716                                      ESP14340
        IF(IIS.EQ.1)THEN                                           ESP14350
        IF(THDG.GT.180.0)THDGI=THDG-180.0                          ESP14360
        IF(THDG.LE.180.0)THDGI=THDG+180.0                          ESP14370
        PHDGI=PHDG                                                 ESP14380
        THETA=THDGI*DTH                                            ESP14390
        PHI=PHDGI*DTH                                              ESP14400
        ENDIF                                                      ESP14410
        IF(IIS.EQ.2)THEN                                           ESP14420
        THETA=THDG*DTH                                             ESP14430
        PHI=PHDG*DTH                                               ESP14440
        ENDIF                                                      ESP14450
        ISCT=IIS                                                   ESP14460
  716   CONTINUE                                                   ESP14470
        IF(INDZI.NE.0)THEN                                         ESP14480
        IF(IANG.EQ.0)THEN                                          ESP14490
        THETA=THINC*DTH                                            ESP14500
        PHI=PHINC*DTH                                              ESP14510
        ENDIF                                                      ESP14520
        IF(IANG.EQ.1)THEN                                          ESP14530
        THETA=THRD*DTH                                             ESP14540
        PHI=PHRD*DTH                                               ESP14550
        ENDIF                                                      ESP14560
        ENDIF                                                      ESP14570
C                                                                  ESP14580
C       INSURE THAT (THETA,PHI) IS IN THE PROPER RANGE             ESP14590
C                                                                  ESP14600
        THETAP=THETA                                               ESP14610
        PHIP=PHI                                                   ESP14620
        THDGO=THETAP/DTH                                           ESP14630
        PHDGO=PHIP/DTH                                             ESP14640
        IF(THETA.GT.1.00001*PI)THEN                                ESP14650
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      THETAP=2.0*PI-THETA                                                ESP14660
      PHIP=PHI+PI                                                        ESP14670
      IF(PHIP.GT.2.00001*PI)PHIP=PHIP-2.0*PI                             ESP14680
      THDG0=THETAP/DTH                                                   ESP14690
      PHDG0=PHIP/DTH                                                     ESP14700
      ENDIF                                                              ESP14710
C     TYPE1111,THETA/DTH,PHI/DTH,THETAP/DTH,PHIP/DTH                     ESP14720
 1111 FORMAT(1X,4F10.3)                                                  ESP14730
C     CALL SORTB(IA,IB,I1,I2,I3,NWR,NM,A,CGD,SGD,FHZ,D,                  ESP14740
C    & IWR,I12,ISCT,ZTF,ZT,IFIL,ICC,ETT,EPP,                            ESP14750
C    & X,Y,Z,NPLTS,NAT,PA,PB,NSA,NPLA,PCN,BDSK,IQUAD,                   ESP14760
C    & NPLTM,IPL,IPLM,CJP,CJT,ETTS,EPPS,ETPS,EPTS,THETAP,PHIP,JA,JB,    ESP14770
C    & SCSP,SCST,SPPM,SPTM,STPM,STTM,IMAGE,ICN,NDNPLT)                  ESP14780
      CALL SORTBN(IA,IB,I1,I2,I3,NWR,NM,A,CGD,SGD,FHZ,D,                 ESP14790
     & IWR,I12,ISCT,ZTF,ZT,IFIL,ICC,ETT,EPP,INTP,INTD,                   ESP14800
     & X,Y,Z,NPLTS,NAT,PA,PB,NSA,NPLA,PCN,BDSK,IQUAD,                    ESP14810
     & NPLTM,IPL,IPLM,CJP,CJT,ETTS,EPPS,ETPS,EPTS,THETAP,PHIP,JA,JB,     ESP14820
     & SCSP,SCST,SPPM,SPTM,STPM,STTM,IMAGE,ICN,NDNPLT,                   ESP14830
     & RF,EXN,EYN,EZN,EXT,EYT,EZT,EXP,EYP,EZP,ERRS,ETRS,EPRS,STRM,SPRM)  ESP14840
  711 CONTINUE                                                           ESP14850
      IF(IANG.EQ.0)GOTO701                                               ESP14860
  710 FORMAT(1X,F10.2,2X,2E20.6)                                         ESP14870
  712 FORMAT(//3X,'SCATERRING PARAMETERS')                               ESP14880
  175 FORMAT(2X,'  THETA=',F10.2,'  PHI=',F10.2,'  SPPM=',E20.6,         ESP14890
     2' STTM=',E20.6,'    IN SQUARE-WAVES')                              ESP14900
  176 FORMAT(2X,'SPPM=',E20.6,'   DB OVER WAVELENGTH-SQUARED')           ESP14910
  173 FORMAT(2X,'STTM=',E20.6,'  DB OVER WAVELENGTH-SQUARED')            ESP14920
      PHTT=BTAN2(AIMAG(ETTS),REAL(ETTS))*180.0/PI                        ESP14930
      PHPP=BTAN2(AIMAG(EPPS),REAL(EPPS))*180.0/PI                        ESP14940
      PHTP=BTAN2(AIMAG(ETPS),REAL(ETPS))*180.0/PI                        ESP14950
      PHPT=BTAN2(AIMAG(EPTS),REAL(EPTS))*180.0/PI                        ESP14960
      PHTR=BTAN2(AIMAG(ETRS),REAL(ETRS))*180.0/PI                        ESP14970
      PHPR=BTAN2(AIMAG(EPRS),REAL(EPRS))*180.0/PI                        ESP14980
      IF(IANG.NE.0.AND.NPLOTS.GT.0.AND.INDZI.EQ.0)WRITE(8,333)           ESP14990
     2 DB(STTM),PHTT,DB(SPPM),PHPP,DB(STPM),PHTP,DB(SPTM),PHPT,          ESP15000
     3 DB(STRM),PHTR,DB(SPRM),PHPR                                       ESP15010
  333 FORMAT(6(1X,F5.1,1X,F6.1))                                         ESP15020
      ETAZ(IANG)=CMPLX(SQRT(STTM),1.0E-20)                               ESP15030
      EPAZ(IANG)=CMPLX(SQRT(SPPM),1.0E-20)                               ESP15040
      STTM=DB(STTM)                                                      ESP15050
      SPPM=DB(SPPM)                                                      ESP15060
      STPM=DB(STPM)                                                      ESP15070
      SPTM=DB(SPTM)                                                      ESP15080
      STRM=DB(STRM)                                                      ESP15090
      SPRM=DB(SPRM)                                                      ESP15100
      IF(IANG.EQ.0.AND.INDZI.NE.0)GOTO701                                ESP15110
      IF(IANG.EQ.1.AND.INDZI.NE.0)THEN                                   ESP15120
      WRITE(6,3190)FMC,STTM,SPPM,STPM,SPTM,PHTT,PHPP,PHTP,PHPT           ESP15130
 3190 FORMAT(1X,F8.2,4(2X,F6.2),4(2X,F6.1))                              ESP15140
      IF(RF.LT.0.0)WRITE(10,3195)FMC,STTM,SPPM,STPM,SPTM,                ESP15150
     2 PHTT,PHPP,PHTP,PHPT                                               ESP15160
 3195 FORMAT(1X,F8.2,4(2X,F6.2),4(2X,F6.1))                              ESP15170
      IF(RF.GE.0.0)WRITE(10,3196)FMC,STTM,SPPM,STPM,SPTM,STRM,SPRM,      ESP15180
     2 PHTT,PHPP,PHTP,PHPT,PHTR,PHPR                                     ESP15190
 3196 FORMAT(1X,F8.2,6(2X,F6.2)/9X,6(2X,F6.1))                           ESP15200
      GOTO701                                                            ESP15210
      ENDIF                                                              ESP15220
      IF(IANG.EQ.1)THEN                                                  ESP15230
      IF(RF.LE.0.0)THEN                                                  ESP15240
      WRITE(6,182)                                                       ESP15250
```

```
  182   FORMAT(//2X,'**(DEG)**  ** CROSS SECTION  (DB/M**2) **  ',      ESP15260
     2  '******   PHASE  (DEG)   ******')                               ESP15270
        WRITE(6,181)                                                    ESP15280
  181   FORMAT(3X,'TH    PHI   STTM    SPPM    STPM    SPTM    STTM',  ESP15290
     2  '    SPPM    STPM    SPTM')                                     ESP15300
        ENDIF                                                           ESP15310
        IF(RF.GT.0.0)THEN                                               ESP15320
        WRITE(6,179)                                                    ESP15330
  179   FORMAT(//3X,'**(DEG)**  ***** NEAR-ZONE CROSS SECTION  ',       ESP15340
     2  '(DB/M**2) *****')                                             ESP15350
        WRITE(6,178)                                                    ESP15360
  178   FORMAT(3X,'TH    PHI   STTM    SPPM    STPM    SPTM    STRM',  ESP15370
     2  '    SPRM')                                                     ESP15380
        ENDIF                                                           ESP15390
        ENDIF                                                           ESP15400
        IF(IANG.GE.1)THEN                                               ESP15410
        IF(RF.LE.0.0)WRITE(6,183)THDGO,PHDGO,STTM,SPPM,STPM,            ESP15420
     2  SPTM,PHTT,PHPP,PHTP,PHPT                                        ESP15430
  183   FORMAT(1X,F6.1,1X,F5.1,4(2X,F6.2),4(2X,F6.1))                   ESP15440
        IF(RF.GT.0.0)WRITE(6,184)THDGO,PHDGO,STTM,SPPM,STPM,            ESP15450
     2  SPTM,STRM,SPRM                                                 ESP15460
  184   FORMAT(1X,F5.1,1X,F5.1,6(2X,F6.2))                              ESP15470
        ENDIF                                                           ESP15480
  701   CONTINUE                                                        ESP15490
 1920  CONTINUE
C***END OF NEW FIXED BISTATIC ANGLE OPTION
        IF(INDZI.NE.0)GOTO3070                                          ESP15500
  916   CONTINUE                                                        ESP15510
        IF(IEA.EQ.1)GOTO918                                             ESP15520
  599   CONTINUE                                                        ESP15530
      CALL GETCP2(KCPU)                                                 ESP15540
CC      CPU=(KCPU-JCPU)/100.0                                           ESP15550
      CPU=(KCPU-JCPU)
        WRITE(6,508)NRUN,NWG,CPU                                        ESP15560
  508   FORMAT(//3X,'CPU RUN TIME FOR RUN',1X,I3,' GEOMETRY',1X,       ESP15570
     2  I3,' = ',F11.2,' SECONDS'/)                                     ESP15580
 3070   CONTINUE                                                        ESP15590
        IF(INDZI.NE.0)THEN                                              ESP15600
        NFFS=NFFS+1                                                     ESP15610
        IF(NFFS.LE.NFF)GOTO3050                                         ESP15620
        ENDIF                                                           ESP15630
  600 CONTINUE                                                          ESP15640
  700 CONTINUE                                                          ESP15650
       CALL GETCP2(LCPU)                                                ESP15660
      CPU=(LCPU-ICPU)
CC    CPU=(LCPU-ICPU)/100.0                                             ESP15670
        WRITE(6,507)CPU                                                 ESP15680
  507   FORMAT(//3X,'TOTAL CPU RUN TIME = ',F11.2,' SECONDS'/)          ESP15690
 9374  STOP                                                             ESP15700
       END                                                              ESP15710
       SUBROUTINE GETCP(ICPU)                                           ESP15720
C      CALL TIMES(DATE,TIME,IVCPU,ITCPU)                                ESP15730
       ICPU=ITCPU*0.0013                                                ESP15740
       RETURN                                                           ESP15750
       END                                                              ESP15760
       SUBROUTINE GETCP2(ICPU)
       REAL ETIME,TARRAY(2)
       TIME=ETIME(TARRAY)
       ICPU=TARRAY(1)
       RETURN
```

```
      END

*****data file    filename esp4nam.ratrplate  (untilted plate)
 &RNCTRL
  NGO=1,NPRINT=2,NRUNS=1,NWGS=1,IWR=0,IWRZT=0,INT=4,INTP=6,INTD=18,
  INWR=0,IRGM=1,IFIL=0,RF=-1.0,INDZI=0,
 &
 &FSWEEP
 &
 &PATTRN
  IFE=0,IPFE=1,FNDFE=3.0,PHFE=90.0,
  IFA=0,IPFA=1,FNDFA=3.0,THFA=90.0,
  ISE=2,IPSE=1,FNDSE=3.0,PHSE=0.0,THIN=90.0,PHIN=0.0,ELRANG=0.,
  ISA=0,IPSA=1,FNDSA=3.0,THSA=90.0,
  IBISC=1,BETA=120.,NPTBIS=121,BANGRG=-360.,
 &
 &FWIRET
  FMC=1300.0,CMM=38.0,A=0.001,NPLTS=1,
 &
 &PLATEG
  NCNRS(1)=4,SEGM(1)=0.2,IREC(1)=0,IPN(1)=3,IGS(1)=0,ZSHT(1)=(0.0,0.0),
  XP(1)=-.4445,0.,.4445,0.,
  YP(1)=0.,-.3429,0.,.3429,
  ZP(1)=0.0,0.0,0.0,0.0,
 &PLATEG
 &
 &SAVEZ
  IWRZM=0,IRDZM=3,
 &
 &WIREAG
  NM=3,NP=4,NAT=1,NFPT=1,NFS1=0,NFS2=0,
  X(1)=0.0,0.0,0.0,-0.3,
  Y(1)=0.0,0.0,0.0,0.0,
  Z(1)=0.0,0.25,0.5,0.25,
  IA(1)=1,2,2,
  IB(1)=2,3,4,
 &
 &GENLOD
  IFMM(1)=3,IABB(1)=0,VLGG(1)=(0.0,0.0),ZLL(1)=(50.0,0.0),
 &
 &ATTACH
  NASAT(1)=1,IABAT(1)=0,NPLA(1)=1,
  VGA(1)=(1.0,0.0),ZLDA(1)=(0.0,0.0),BDSK(1)=0.4,
 &

****data file    filename esp4nam.ratrtiltp  (tilted plate)

 &RNCTRL
  NGO=1,NPRINT=2,NRUNS=1,NWGS=1,IWR=0,IWRZT=0,INT=4,INTP=6,INTD=18,
  INWR=0,IRGM=1,IFIL=0,RF=-1.0,INDZI=0,
 &
 &FSWEEP
 &
 &PATTRN
  IFE=0,IPFE=1,FNDFE=3.0,PHFE=90.0,
  IFA=0,IPFA=1,FNDFA=3.0,THFA=90.0,
  ISE=2,IPSE=1,FNDSE=3.0,PHSE=0.0,THIN=90.0,PHIN=0.0,ELRANG=0.,
  ISA=0,IPSA=1,FNDSA=3.0,THSA=90.0,
  IBISC=1,BETA=120.,NPTBIS=121,BANGRG=-360.,
 &
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```
 &FWIRET
  FMC=1300.0,CMM=38.0,A=0.001,NPLTS=1,
 &
 &PLATEG
  NCNRS(1)=4,SEGM(1)=0.2,IREC(1)=0,IPN(1)=3,IGS(1)=0,ZSHT(1)=(0.0,0.0),
  XP(1)=-.4445,0.,.4445,0.,
  YP(1)=0.,-.2425,0.,.2425,
  ZP(1)=0.0,.2425,0.0,-.2425,
 &
 &PLATEG
 &
 &SAVEZ
  IWRZM=0,IRDZM=3,
 &
 &WIREAG
  NM=3,NP=4,NAT=1,NFPT=1,NFS1=0,NFS2=0,
  X(1)=0.0,0.0,0.0,-0.3,
  Y(1)=0.0,0.0,0.0,0.0,
  Z(1)=0.0,0.25,0.5,0.25,
  IA(1)=1,2,2,
  IB(1)=2,3,4,
 &
 &GENLOD
  IFMM(1)=3,IABB(1)=0,VLGG(1)=(0.0,0.0),ZLL(1)=(50.0,0.0),
 &
 &ATTACH
  NASAT(1)=1,IABAT(1)=0,NPLA(1)=1,
  VGA(1)=(1.0,0.0),ZLDA(1)=(0.0,0.0),BDSK(1)=0.4,
 &
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Alan J. Fenn

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13. ABSTRACT *(Maximum 200 words)*

The bistatic radar cross section of a perfectly conducting flat plate that has a rhombus shape (equilateral parallelogram) is investigated. The Ohio State University electromagnetic surface patch code (ESP version 4) is used to compute the theoretical bistatic radar cross section of a 35- × 27-in rhombus plate at 1.3 GHz over the bistatic angles 15° to 142°. The ESP-4 computer code is a method of moments FORTRAN-77 program which can analyze general configurations of plates and wires. This code has been installed and modified at Lincoln Laboratory on a SUN 3 computer network. Details of the code modifications are described. Comparisons of the method of moments simulations and measurements of the rhombus plate are made. It is shown that the ESP-4 computer code provides a high degree of accuracy in the calculation of copolarized and cross-polarized bistatic radar cross section patterns.

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